In studying the admissions of mentally defective children to a state school the authors of this investigation found the occurrence of this condition is apparently related to the season of conception. They offer a possible explanation with important public health consequences.

SEASONAL VARIATION IN THE BIRTHS OF THE MENTALLY DEFICIENT

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IT IS well known that the time at which injury to the developing fetus occurs results in a differential effect on the production of congenital anomalies. The embryonic stage, rather than the specific nature of the prenatal stress, appears to determine the type of malformation that will appear. Defects will manifest themselves in those organ systems that are undergoing the greatest amount of differentiation or organization at the time of the injury.[1] In the central nervous system[2] damage which occurs prior to the eighth week of fetal life usually results in gross anomalies, many of which are incompatible with life. During the eighth to 12th week the cerebral cortex is undergoing its organization into the various molecular layers, and this period would be the critical time during which maternal stress would be apt to lead to those neuropsychiatric disabilities which result from cortical disorganization.

Infectious diseases play prominent roles in the production of central nervous system damage. Congenital lues in the past was one of the major conditions which acted during fetal life to produce remote as well as immediate damage to the brain. In the more recent past reports have appeared about the effect of rubella in the first trimester of pregnancy in the production of several central nervous system defects. Viral infections operate in the postnatal period to damage the brain and their effects are easily observed. The influence of similar infections in the mother during pregnancy is not as easily subjected to investigation, but it may be equally if not more important.

As a starting point, one of a series of neuropsychiatric disabilities—mental deficiency—was selected and a study designed to test the hypothesis that, because of the variation in the prevalence of viral infection, differences in the incidence of mental deficiency would occur which would be dependent on the season of birth. Infants conceived in the winter months it was postulated would have an increased incidence of mental deficiency when compared to infants conceived in the summer months, because of the increase in the prevalence of these infections during the colder seasons.

Materials and Method of Study

The birth dates of all individuals who had ever been admitted to the Columbus State School were supplied by the Statistical Bureau of the Division of

Mental Hygiene; patients who were born between 1860 and 1949 were included. The number of admissions in the years before the turn of the century and even well into the twentieth century was obviously small, either because of the incompleteness of the records or because of the limited facilities available. Likewise, because of the policy of the school of not admitting children under the age of six years, less than a dozen were born after 1948 at the time that the list was compiled. Since a minimum of 100 individuals per year was admitted from 1913 through 1948, the analysis was made on patients born in those years.

The number of births in each month was supplied by the Ohio State Health Department. These data were available for all of the years during which adequate numbers of admissions occurred with the exception of 1946, and this year was consequently eliminated from consideration. A rate which can be considered a "first admission rate" was then calculated according to the month of birth for those years already delineated above. This rate would express the seasonal variation in births of the mentally deficient. It is obviously not a precise expression of the differential incidence of mental deficiency, but is sufficiently analogous to permit substitution of the single word "incidence" for the more cumbersome phraseology.

It was recognized that, at the very most, only 10 per cent of all of the mental defectives born in the state were admitted to the Columbus State School. Admissions are allocated to the 88 counties of the state strictly on the basis of county population, some counties having 24 admissions per year and some many times that number. Since the children are six years of age by the time that they are admitted, month of birth is not likely to be a factor taken into consideration in any decision to admit a child. It was also recognized that neither could account be taken of the precise amount of in- and out-migration; we do not believe that a decision to move is influenced by the month in which a child is born, however. There is no reason to believe, therefore, that bias would be introduced by either of these factors because of season of birth.

Findings and Discussion

There is variation in the "first admission rate" for mental deficiency and the rate per 1,000 live births by month of birth is shown in Table 1. Contrary to what was predicted by the hypothesis, however, the greatest incidence occurs not in the late summer and early fall months but rather in the winter months, the peak being found in February. This highest rate of 1.507 per 1,000 births for February is significantly higher than the rate of 1.297 for its seasonal counterpart for August (C.R.=2.36; $P<0.02$). Likewise, the rate of 1.442 for the first three months of the year is significantly higher than the rate of 1.318 for the contrasting months of July, August, and September (C.R.=2.43; $P<0.02$). These data are shown in Table 2. For the infants born in February the critical eighth to 12th week of the gestation period would be the month of July.

Several possible explanations for this finding immediately come to mind. Since there is a higher admission rate to the Columbus State School from the lower socioeconomic groups and also a higher incidence of mental deficiency in these groups, any differential between upper and lower socioeconomic groups in the planning of pregnancies would be reflected in the number of patients born in each of the different seasons. The assumption would be, then, that the upper economic groups planned their pregnancies so that their babies were delivered in July and August. This explanation has already been suggested by Goodenough [3] as the explanation for her observation of a slight superiority

Table 1—Mental Deficiency First Admission Rates by Month of Birth, Columbus State School, 1913–1948 (Excluding 1946)

Months	No. of Births	No. of Admissions	Rate/1,000
January	358,848	503	1.402
February	339,704	512	1.507
March	365,631	520	1.422
April	342,624	475	1.386
May	350,131	485	1.385
June	349,894	472	1.349
July	373,853	494	1.321
August	377,085	489	1.297
September	361,995	484	1.337
October	354,558	463	1.306
November	334,113	473	1.416
December	342,881	485	1.414
Total	4,251,317	5,855	1.377

in IQ's of school children born in the summer months. It would not seem logical to plan to have children in the two hottest months of the year, but fortunately data are available and it is possible to examine the facts without having to inquire into motives.

There is a significant difference in the number of births by month. Analysis of some four million births in Ohio in the period from 1910 to 1955 indicates that the highest birth rates occur in July, August, and September. There is, curiously enough, another peak in February. Data on over 160,000 births in New York City in 1956 show a similar pattern. Data on approximately 23,000 births in Baltimore were used in comparing the upper and lower socioeconomic groups. Census tract of residence was the criterion for placing a birth into a given economic 10th of the population. The peak number of births for the smaller series

Table 2—"First Admission Rates" for Mental Deficiency by Season of Birth, Columbus State School, 1913–1948 (Excluding 1946)

Season	No. of Births	No. of Admissions	Rate/1,000	
February	339,704	512	1.507	C.R. = 2.3 $P < 0.02$
August	377,085	489	1.297	
January, February, and March	1,064,183	1535	1.442	C.R. = 2.4 $P < 0.02$
July, August, and September	1,112,933	1467	1.318	

tends to be in September, October, and November. There are, however, no significant differences according to socioeconomic status; if anything, there appears to be a somewhat higher birth rate for the upper socioeconomic groups for the winter period when compared to the lower socioeconomic groups. Differential planning of birth appears, therefore, to be an inadequate explanation for the seasonal variations in the births of the mentally deficient.

Mills has written extensively on the effects of climate on health and disease in man and animals. He indicates,[4] for instance, that in the rat thiamin requirement doubles as the temperature changes from 65° F to 90° F. Members of the vitamin B complex act as catalysts at specific stages in glucose combustion and there has been much speculation about the effects of the alteration in the metabolism of glucose on the functioning of the central nervous system. In rats there are also many differences in learning and retention when litter mates kept on uniform diets for three months are reared in temperatures of 55° F, 75° F, and 90° F.[5] This effect apparently carries over to human beings as well. As only one example, students taking college entrance examinations during the summer achieve only about 60 per cent of the ratings obtained on the same examination given in the winter.

More important than performance under diverse environmental conditions, perhaps, is the relation of the month of conception to certain later functions. Mills reports that children in the Cincinnati latitudes who are conceived in the summer months have just half the chance of entering college as those conceived in the winter months. There is a low likelihood of being included in "Who's Who" if there is a summer conception and only four out of the 33 presidents were conceived in the third quarter of the year. Peterson [6] has shown findings similar to those of our own, namely that feeble-minded children are more frequently conceived in the summer months. Mills [7] tends to attribute all of these findings to the beneficial effects of atmospheric instability and environmental stimulation, and the consequent greater metabolic potential of the germ cells.

Mills [5] also mentions that it has been shown, in animals at least, that it is possible to control the depressing effects of heat by adequate diet, particularly in respect to the vitamins and protein, and he points out that it is probably necessary to have proportionately more protein to meet the minimum requirements during the summer months when the total caloric intake is reduced.

In a study of a group of New Haven Negro infants born during the years of World War II [8] we demonstrated that white physical and behavioral developmental norms were followed. The only intragroup correlation was the significant superiority of those infants who were above weight at birth, as well as at the time of examination, over the infants who were below the median in weight at both times. It was felt that these findings could be explained on the basis of adequate prenatal care and adequate nutrition during pregnancy consequent to increased employment and wartime rationing.

On the basis of these findings it was postulated that the relationship between temperature and intellectual performance might, perhaps, be greatly influenced by the fact that the diet of the mothers may be poor in the hotter months of the year, and that this lowered dietary intake exerts its greatest effect during the eighth to 12th week of gestation. If this were true, then it should be possible to demonstrate a difference in the incidence of mental deficiency on the basis of variations in temperature from one year to another.

Accordingly, the monthly mean temperatures for the six largest Ohio cities

for which data were available were averaged. The temperatures during June, July, and August were those considered, since these were the months in which the eighth to 12th week of gestation corresponded to those months of the year with the highest incidence of mental deficiency. The years in which the mean temperature was above the median were then contrasted with those years in which the temperature was below the median. These data were also based on the years from 1913 to 1948.

The differences in the "first admission rates" for mental deficiency, according to whether the mean temperature for the month was above or below the median, are shown in Table 3. When the eighth to 12th week of pregnancy occurred in June, there are no significant differences in the incidence of mental deficiency between those years with temperatures below and above the median. For July and August the differences are highly significant. The rates in those years where the average temperature was above the median were 1.658 per 1,000 births for July and 1.519 for August, compared to rates of 1.276 and 1.206, respectively, in those years when the average temperature was below the median. Likewise, the differences for the total three-month period of June, July, and August were highly significant, being 1.524 for those years where the weather was hot compared to 1.295 for the cooler years ($X^2=10.02$; $P<0.001$). These differences between the warmer and cooler summers are greater than the differences observed between babies born in the first three months of the year and those born in the third quarter. The difference for the month of July on the basis of mean temperature is actually three times as great as the difference between the first and third quarters of all of the years under investigation. These highly significant differences would tend to support the hypothesis that inadequate dietary intake in early pregnancy during the hot summer months has an adverse effect on the development of the child. The number of cases was too small to permit analysis of variations from one season to another from year to year. Before combining all of the years together, however, variation in rates from

Table 3—"First Admission Rates" for Mental Deficiency by Month of Birth According to Mean Temperature During the 8th to 12th Week of Pregnancy, Columbus State School, 1913–1948 (Excluding 1946)

		8th to 12th Week of Pregnancy			
		June	July	August	Total
Mean Temperature		70.19	74.30	72.73	....
Temperature Below Median	No. of Births	170,788	175,522	186,494	532,804
	Admission Rate/1,000 Births	1.411	1.276	1.206	1.295
Temperature Above Median	No. of Births	181,126	171,293	187,598	540,017
	Admission Rate/1,000 Births	1.402	1.658	1.519	1.524

$X^2 = 10.02$
$P < 0.001$

one year to the next was examined. It was immediately obvious that in the depression years the rates were very much higher than in the nondepression years in both the post-World War I depression and the depression of the 1930's. However, the temperature differences for the so-called "boom years" and for the "depression years" were the same as for the total. Within each group the hotter summers were followed by a higher incidence of mental deficiency in the winter months, regardless of whether the over-all rate for the block of years was high, as in the depression years, or low, as in the boom group.

These findings appear to form one more link in the chain of events demonstrated by our previous studies of the association of prenatal and paranatal factors with the development of neuropsychiatric disabilities and the hypothesis of a continuum of reproductive casualty. These previous studies indicated that the complications of pre- and paranatal periods, particularly the chronic anoxia producing ones, such as toxemia and bleeding, and prematurity, were associated with an increased incidence of a series of clinical conditions ranging from cerebral palsy [9] through epilepsy,[10] mental deficiency,[11] behavior disturbances,[12] reading disturbances,[13] and tics.[14] A higher incidence of these complications of pregnancy was demonstrated in the lower socioeconomic groups [15, 16] where dietary factors might be of considerable importance. Some authors [17] have demonstrated that toxemia of pregnancy can be prevented by supplying a diet adequate in protein and vitamins to the mother during gestation and at this time probably the most widely accepted theory of the cause of the toxemias of pregnancy is inadequate protein intake. There may, of course, also be a direct effect of protein deprivation on the production of mental deficiency per se without the necessity of the intermediary influence of toxemia. There have been many reports on a number of differences in infants whose mothers' diets have varied during pregnancy.

Under these theoretical assumptions one would expect to find differences similar to those in mental deficiency in the incidence of complications of pregnancy, and obstetricians are aware of a seasonal variation in toxemia. The New York City Health Department supplied data on the proportion of live birth certificates reporting one or more pathological conditions during pregnancy in 1956. Findings to be reported elsewhere indicate that all of the complications of pregnancy predicted by the hypothesis are significantly higher in the winter months.

These findings do not invalidate the infection hypothesis or preclude other explanations for the differences found. Infectious diseases probably play an important role prenatally. Since it is more likely that they act to a larger extent in the winter months rather than in the summer, these findings are only strengthened. As a matter of fact, the incidence of summer encephalitis was examined in an attempt to correlate it with the rates of admissions for mental deficiency and it was found that the rates were lower in the years when encephalitis was high in the summer months, although not significantly so. Another factor that immediately comes to mind as being associated with hot summer weather is salt depletion and this may very well play a role, the exact nature of which is not immediately clear at the present time.

There are, undoubtedly, complex interactions of many environmental influences which alter susceptibilities and change the manifestations of central nervous system damage. We are engaged in further investigations which may elucidate the etiologic factors and open up greater possibilities for prevention. A host of additional epidemiologic studies immediately comes to mind

—an investigation of all the neuropsychiatric disabilities and complications of pregnancy by seasonal and temperature variation; the effect of geographic location on the production of differences in incidence; the influence of hyperemesis gravidarum on the development of the child. Intensification of dietary and behavioral experimentation with laboratory animals, where the experimenter can vary conditions at will, also appears indicated.

These findings also add to the mounting body of evidence, based on studies done by others as well as ourselves, that the characteristics of a human being are far from being immutably determined by the genes at the moment of conception. Environmental factors act continuously on the fetus from this moment, if they have not already significantly affected the parents also, to determine the anatomical structure as well as behavioral functioning. Except for a comparatively few and rare hereditary disorders, life experiences, rather than inherited characteristics, may be the primary factors making one individual significantly different from the next.

It does not appear necessary, however, to wait until the last iota of evidence is in proving the association of diet and disability. Present knowledge, exclusive of the results of this study, would appear sufficient to demand that public health workers turn their attention more directly to this problem. We are well beyond the stage of paying lip service to the importance of the chronic diseases; possible avenues for prevention should be seized upon—and action taken. In a field as complex as behavioral functioning prevention of dysfunction is often the only method of demonstrating etiology.

The possibility of dietary control in the prevention of disability need not be confined to efforts in this country, even though we recognize the tremendous cost of the neuropsychiatric disabilities in terms of chronicity, loss of productivity, family dislocation, and the need for provision of care.

There may be much more to gain in the developing countries which are, by and large, the tropical ones. The inability to improve productivity to support their increase in population, which is largely a result of public health measures in controlling acute infectious diseases, may well hinge on the long-term effects of diets which we know to be suboptimal. It seems likely that this damaging influence is acting not only on the present generation, but also on future individuals yet unborn to produce a whole series of neuropsychiatric disabilities. Breaking the vicious cycle by a concerted attack at one point, namely, women in the child-bearing period, could be extremely rewarding.

Summary

In studying the admissions of mentally defective children, born in the years 1913–1948, to the Columbus State School, it was found that significantly more had been born in the winter months, January, February, and March. Since the third month after conception is known to be the period during pregnancy when the cerebral cortex of the unborn child is becoming organized, any damage which occurred at that time could affect intellectual functioning. The months when this might happen would be June, July, and August, the hot summer months, when pregnant women might decrease their food intake, particularly protein, to dangerously low levels and consequently damage their developing babies. If this were so, one would expect that hotter summers would result in significantly more mental defectives born than following cooler summers. This was exactly what was found to a highly significant degree. Possible explanations of the above findings were sought in the occurrence of summer

encephalitis and an increased birth rate in the lower socioeconomic group, but these were not confirmed.

These findings have wide public health implications, since the writers have shown previously not only that physical growth is affected by what happens to the unborn child but also that cerebral palsy, epilepsy, and even behavior and reading disorders may follow damage during this period. There is a growing body of evidence which indicates that it is very important for women in the child-bearing age to have good diets if they are to produce healthy, normally developing children. Inadequate dietary intake during pregnancy, because of heat as well as substandard economic conditions, may be an important link in the vicious cycle that results in poor physical and mental growth.

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