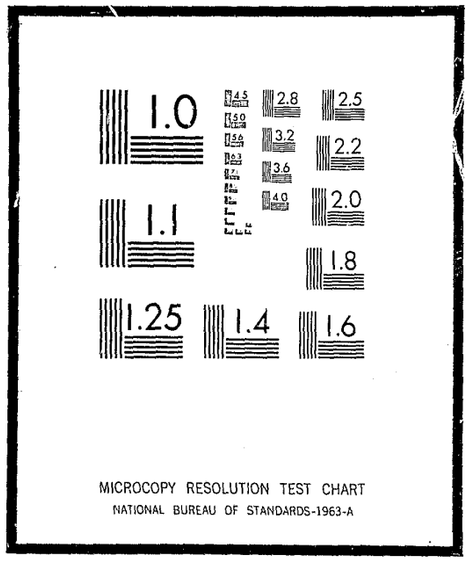

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XYY Chromosome Genetics *

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That all men are created equal is a concept which depends on ethical and religious principles not on scientific principles. Equality of rights is one thing, equality of physical and mental endowment yet another. The observations of daily living attest to the diversity of physical types, the diversity of mental abilities and the immense range of behavioral responses present in our fellow humans.

It is a common belief, even in our democratic society, that there are good and poor stocks of men and that certain types give rise to long lines of honorable people—lawyers, doctors, statesmen—while other types give rise to lines whose members fail to adapt to an orderly society. The apprehension that most parents would feel if a daughter married a perfectly good man with a "bad" family background would not be only socially oriented, but the heredity question probably also would be a cause of worry.

Therefore, when evidence is brought forward to show that certain antisocial types have a traceable, inherited abnormality, the normal man is likely to accept the whole hypothesis because he has been conditioned toward believing in such phenomena all his life. Such evidence has been brought forward in the case of the individual with an XYY chromosome makeup in terms of correlation between criminal violence and genetic constitution. This discussion will attempt to give some of the genetic back-

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ground of the XYY problem and to evaluate the data which are now available.

The genetic material is contained primarily in the nucleus of each cell of an individual's body. During most of the life of a cell this material is identifiable only as nucleus in differentiation from the cytoplasm. However, shortly before a cell undergoes division, the genetic material takes on a characteristic form as it condenses in the nucleus. As this process continues, elongated bodies formed by the repeated coiling of long molecules take shape. If the cell is broken open at the stage of maximum condensation of genetic material and the material stained, these bodies can be characterized (Fig. 1). Cells of a normal individual contain 22 morphological pairs of staining bodies, called chromosomes, plus a 23rd pair of chromosomes which may or may not be morphologically identical (Fig. 2). This 23rd pair comprise the sex-determining chromosomes; the other 22 pairs are referred to as autosomes. Females have two identical sex chromosomes (XX) and males have an X chromosome and one small Y chromosome (Fig. 3). The picture generated when chromosomes are arranged in pairs is called a karyotype.

Fig. 1—Chromosomes recovered from one cell prior to division into two daughter cells. Fig. 3 was generated from this spread. The Y chromosome is on the right edge of the picture.

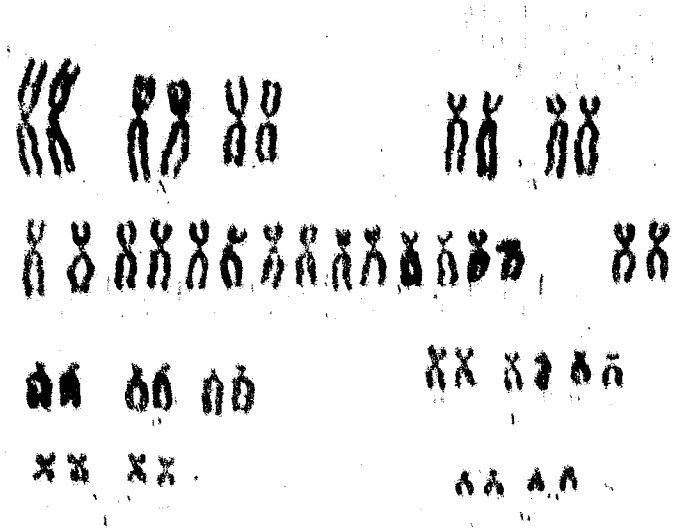

Fig. 2—Karyotype of a normal female. Note the presence of two X chromosomes and no Y chromosome.

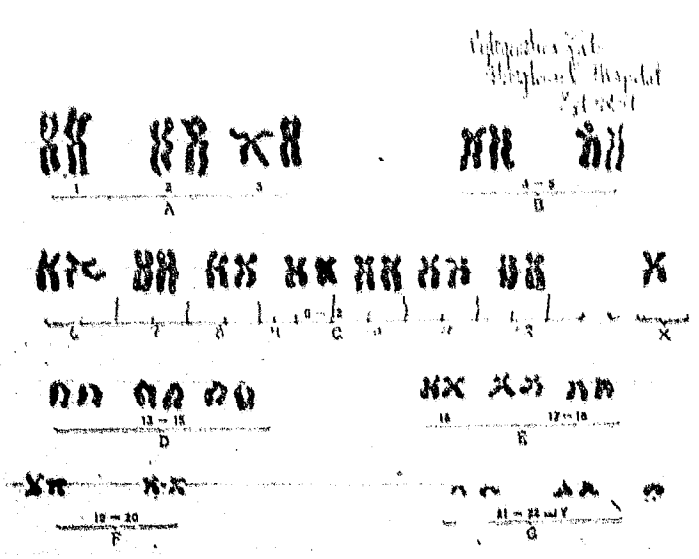

Fig. 3—Karyotype of a normal male generated from Fig. 1. Note the presence of one X chromosome and one Y chromosome.

That the Y chromosome is the major determinant of the sex of a human is readily shown by the fact that an individual who has only one X chromosome and no Y chromosome is a female in habitus although she may lack ovaries and have other abnormalities; also an individual with two X chromosomes and one Y chromosome is a male in habitus although he may have dysfunctional testes and some breast formation as well as other abnormalities. An important point to remember is that sex determination is not solely governed by presence of the Y chromosome. The most striking example in this case is a recessive gene, *not* a chromosome, which changes an XY individual into an individual with a female habitus, and since the person with this genetic makeup is raised as a girl, the psychology of such a person is female (1).

Imbalance in genetic material for any of the 22 pairs of non-sex chromosomes (autosomes) has dire consequences, causing early death to the fetus or newborn. Only the mongoloid child with three #21 chromosomes survives, but with physical and mental impairment. Imbalance in the sex chromosome complement, however, is often compatible with life. XO and XXY individuals are known and rather well studied, and XXX, XXYY, XXXY, etc., individuals are also known. In general, as the imbalance increases so also do the physical stigmata, as well as accompanying mental retardation. Male-like individuals or female-like individuals with a sex chromosome imbalance are referred to as genetic intersexes. Such individuals are usually ascertained because of the physical abnormalities they possess.

Methods are available for rather rapid and inexpensive testing for an abnormal number of X chromosomes in an individual without generating karyotypes. Females with two X chromosomes have one dark staining body (Barr Body) on the periphery of their cell nuclei while normal XY males do not. Lack of a Barr Body in a morphological female leads one to suspect an XO condition and presence of a Barr Body in an apparent male is generally the result of the extra X in an XXY individual. Therefore, the presence of a Barr Body indicates a second X chromosome, two Barr Bodies—a second and third X chromosome. Barr Bodies do not provide evidence regarding the number of Y chromosomes present. Barr Bodies are generally identified in cells from the epithelium of the buccal cavity (cheek

cells). These may be obtained quickly and without pain, and fixation and staining is relatively inexpensive.

This method has been used to survey populations for sex chromosome imbalance (2). The procedure will miss all XYY individuals and this fact has been overlooked in some popular reports which give data from general studies which failed to show any XYY individuals in a combined total of over 13,000 people tested. The inference is that XYY individuals are therefore exceedingly rare. Court Brown, whose excellent review was published in December 1968, presents better arguments and some data as to the frequency of XYY males in the population (3). In his estimate they are less frequent than 1.3 per thousand male births. More recent data, probably not available to Court Brown at the time of writing his review, has been presented by Sergovich, who did chromosome studies on 1,066 consecutive male births at a Canadian hospital and found four XYY individuals for a possible incidence of about one in 250 (4).

All the data relating to the frequency of the XYY individual in the general population which are available are from Caucasian populations and are extremely sparse; however, it seems safe to estimate the rate to be about one per thousand or somewhat more frequent. There is no a priori reason to believe that racial differences will be correlated with different frequencies of XYY individuals. Perhaps differences in prenatal and postnatal care may alter the frequency in the surviving populations through differential mortality of XYY individuals.

We are left with the problem of genetic determination of behavior and the possibility that an XYY individual is not responsible for his actions. The data which support this view are the high frequency of XYY men imprisoned for violent crime. Jacobs et al. (5, 6) found nine XYY individuals in a population of 315 men examined in a maximum security hospital in Scotland, or about 3 percent of this population. If the frequency in the general population is about 0.1 percent, then 30 times more are confined in this hospital than one would expect if confinement were uninfluenced by XY–XYY differences. Similar data collected in Britain and the U. S. support these results; however, only special types of prisons which deal with offenders who have committed violent crimes against property or persons have an obvious increase in XYY inmates over the population mean.

Of great importance in studies to date is the fact that XYY individuals do not generally come from a criminal environment. Price and Whatmore (7, 8) showed that only one of the 31 sibs of these nine XYY individuals had been convicted of a criminal offense while 18 XY males who were in the same criminal class as the test males had 139 convictions recorded for their 63 sibs. Thus, the XYY offender stands out as a black sheep of his family, coming from a relatively crime-free background, while the XY offender generally comes from a criminal environment. Such data support the hypothesis that the XYY's behavior is attributable to his unique genetic makeup. Further studies have shown that the testosterone concentration in selected criminal XYY individuals is often significantly higher than in the "normal" male (9).

However, it seems equally evident that having an XYY chromosome pattern is not in itself a determinant of violent criminal behavior. The first case of an XYY reported was in a normal man being studied for problems unrelated to the present topic (10). More recently Wiener and Sutherland, again by accident, found an XYY individual "of cheerful disposition and mild temperament" (11). Other XYY individuals have been found who presented infertility problems or abnormal sexual development, including undescended testes and hypogonadism. Such individuals would hardly be expected to show increased testosterone excretions.

Scotland is perhaps the best studied area for the presence of imprisoned XYY individuals. Nevertheless, on a projected population frequency of one per thousand, only two percent of all Scottish XYY men, thought to be living today, have been ascertained. Where are the others? What is their behavior?

There are many unknowns in what popular writing likes to portray as the concise science of genetics, and no branch of this science has a more challenging and complex task than the area known as behavioral genetics.

One factor which complicates the science of genetics is that genes do not operate in a vacuum but are dependent on other genes and the environment. Thus, every gene and, a fortiori, every complex of genes has a range of reaction to the environment in which it is found. For example, there is a gene which causes polydactyly (extra digits). This gene is present in all the

cells of some individuals and yet they may have only five fingers and five toes on each hand and foot. Others will have one extra toe or one extra finger or one extra on one hand and two extra on the other, etc. The gene has a wide range of reaction. Perhaps more to the point is the wide range of reaction one sees in Down's Syndrome (mongolism; extra chromosome 21). Some Down's children have rather gross retardation, major heart anomalies, and many fail to survive infancy; on the other hand, some have a rather mild retardation (75–80 I. Q.), no major heart defects, and have lived to at least middle age. An individual carrying a gene or genes which cause retardation may be more or less retarded depending on the other genetic factors and the external environment which is at work.

The XYY syndrome also displays a wide range of reaction, with apparently normal individuals, individuals with hypogonadism, and violent criminals being found in the spectrum. What the factors are, genetic or environmental, which determine where any particular XYY individual may be on the spectrum are at present unknown.

It is reasonably certain that genetic factors do condition behavioral responses. A dwarf seldom steals from shelves more than five feet above the floor, and many individuals do well to control their temper some of the time, while others find it difficult to work up enthusiasm for anything. These are all broadly behavioral traits conditioned by genetic makeup but with many other variables complicating the landscape. It is the belief of the author that the behavior of an individual is still scientifically unpredictable, given what presently can be known about his genetics. For the immediate future all that can be reasonably hoped for is a clearer knowledge of the range of reaction of the XYY genotype and the percentage of individuals who fall within various areas of this range.

Summary

An XYY chromosome makeup has been correlated with violent criminal behavior. Significantly more XYY men are found in maximum security prison/hospitals than would be expected by chance. However, less than five percent of living XYY men have been found confined in such institutions. "Normal" men can have an XYY karyotype as well as men with hypogonadism

or undescended testes. Thus, the range of reaction of this particular genetic type is broad and the factors which determine where any affected individual will eventually fit are unknown.

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