view, one can still note that the trial continued even after this view was no longer accepted in the scientific community. Designed around a problematic and ultimately untenable perspective, the results of the study lack any scientific or medical value.

A LESSON FOR RESEARCH ETHICS
In courses on medical ethics and research ethics around the country (and perhaps even further), the Tuskegee syphilis study, alongside the Nazi experiments during World War II (1939–1945) and the Willowbrook studies of hepatitis in mentally disabled children from 1956 to 1971, is used as an example of medical research gone wrong. The difference is that the Nazi experiments and the Willowbrook studies both produced useful knowledge (the Nazi experiments produced a wide array of knowledge about the physiological workings and limits of the human body, and the Willowbrook studies correctly identified the distinction and the possibility of inoculation for hepatitis A and B), while the syphilis study produced nothing of value. The Tuskegee syphilis study reminds us that medical research can use ethically impermissible methods to achieve many things, but medical research can also fail to accomplish anything more than an expression of the worst of our social views.

SEE ALSO Disease; Ethics in Experimentation; Ethnobiological Methodology; Experiments, Human; Informed Consent; Racism

BIBLIOGRAPHY

Abraham P. Schwab

TUTU, DESMOND
SEE Apartheid; Mandela, Winnie; Truth and Reconciliation Commissions.

TVERSKY, AMOS
SEE Rationality.
Twin Studies

and population. (3) Estimates of heritability describe the genetic variance within a given population; they are not valid for comparisons between different populations. (4) Environmental conditions may improve the strength of the heritability estimates. (5) Heritability does not necessarily measure the genetic contribution to a trait. Suppose, for example, a researcher is interested in using the classical twin-study method to find a heritability estimate for the condition of having two eyes. The researcher would find that, in most cases, all of their MZ and DZ participants have two eyes, thereby expressing no variance, and resulting in a heritability estimate of zero.

Calculating $b^2$ from classical twin studies rests on an important premise: the equal environment assumption (EEA). Since MZ twins share 100 percent of their genetic material, and DZ twins share on average only 50 percent, one might assume that any observed differences between the two types of twins are due to genetic variance. However, in order to calculate $b^2$ from classical twin studies, researchers must first assume that MZ twins and DZ twins share the same environment, thus allowing researchers to isolate the magnitude of genetic influences on a trait without environmental confounds. Critics of twin studies have long pointed out that MZ twins generally experience environmental conditions and treatment that are more similar than that experienced by DZ twins, particularly if the DZ twins are of different genders.

In response to such criticism, twin-study proponents reformulated the EEA into the equal trait-relevant environment assumption (trait-relevant EEA), which assumes that MZ and DZ twins have equal exposure to only those environmental influences of known relevance to the trait under study. But critics of the trait-relevant EEA argue that MZ twins spend more time together, are more likely to engage in similar activities, are similarly treated by others, and are more likely to have similar friends than DZ twins. Therefore, since MZ twins experience a more similar environment than DZ twins overall, they are also more likely to have greater exposure to environmental influences that affect a given trait than DZ twins.

In addition to the classical twin study, other methodologies are available for comparing the differences between twins. The co-twin control method is the only twin-study design that attempts to manipulate environmental influences. In this type of study, the genetic component is held constant, and the researcher manipulates the environment. Only MZ twins can be used in such a study. One twin becomes the control participant, while the other is given an environmental intervention. Scores on the trait of interest are measured before and after environmental manipulation. The correlation between the twin pairs before the intervention is measured against the correlation in their scores afterward. The resulting coefficient is a measure of the effects of the environment on the trait under study. This method, however, has largely been discontinued due to its history of misuse, most notably in the twin studies conducted by Nazi doctor Josef Mengele (1911–1979) at the Auschwitz concentration camp during World War II (1939–1945).

Adoption studies are often referred to as twins-reared-apart studies, since one or both of the twins is separated from the biological parents and placed with a relative or an adoptive or foster family. Typically, MZ twins who are reared apart (MZA) are compared to MZ twins reared together (MZT). In adoption studies, correlations of MZAs on a given trait are compared to MZTs. Occasionally, DZ twins reared apart are used as well. In most cases, researchers are interested in establishing trait similarity across a number of different measures. The underlying assumption of adoption studies is that twins have been placed randomly into homes, with minimal or no contact with each other. Although this assumption is almost never accurate, the results from twins-reared-apart studies have been very influential in the social sciences.

The most significant twin-study findings resulted from two large-scale systematic adoption studies: the Minnesota Study of Twins Reared Apart (beginning in 1983) and the Swedish Adoption/Twin Study of Aging (beginning in 1984). These studies reported medium to high correlations between MZAs and MZTs on a number of variables, including IQ, physical traits, and a long list of personality traits. In addition, the Swedish Adoption/Twin Study found moderate to high correlations for processes specifically related to aging, such as memory decline. The conclusion reached in these studies is that genetics are responsible for trait similarity, and that environmental factors have little influence. Critics of these results have pointed to researcher bias, vague or missing data, the denial of access to collected raw data, and the dubious separation of the twins involved in the studies.

Genetics research has at times generated heated ethical and political debates. For example, some authors have commented that studying the genetic components of traits will lead to a resurgence in the eugenics movement and, in particular, the misuse of heritability research on intelligence by some proponents of genetic engineering. Despite these concerns, twin studies and the field of behavioral genetics have had an undeniable impact in the sciences and culture. The progress of this field of research has helped to shift the public discourse on genetic research in favorable directions. With advances in microgenetic research and the continuing development of genomic sciences—particularly as they relate to health promotion and disease prevention—twin studies are likely to become a less-prominent technique for estimating genetic effects than they have been in the past. In any case, because of the
methodological shortcomings of twin studies, the estimates that such studies provide for the heritability of attributes and processes should be analyzed carefully and critically.

SEE ALSO Determinism, Biological; Determinism, Environmental; Eugenics; Genomics; Heredity; IQ Controversy; Nature vs. Nurture; Sibling Relationships; Social Science; Trait Inference; Trait Theory

BIBLIOGRAPHY


Laura C. Ball

Thomas Teo

TWINS

SEE Multiple Births.

TWO-SECTOR MODELS

Broadly speaking, the two-sector model is an analytical framework that embodies stylized dynamic economies with two production processes. Each sector is devoted to the production of a unique good, and there are usually two factors of production that can freely move across sectors. This analytical framework abandons the rather limiting restriction of the one-sector model, in which the same aggregate good is devoted to both consumption and capital. The two-sector framework allows for the study of dynamic effects of economic policies on each sector and the possible interactions between the two sectors. These effects can also be studied in models with several sectors of production, though in these latter models the analysis may not be tractable. Two-sector models are found in many areas of economics. In international economics, the two-sector framework arises naturally in economies with tradable and non-tradable goods. In analyses of economic growth, the distinction is usually between consumption and capital. More recent research has focused on other pairings: physical and human capital, physical production and R&D, home and market goods, and cash and credit goods.

John R. Hicks (1937) introduced a two-sector model for examinations of consumption and investment, as a way to compare the predictions of newly developed Keynesian theories with what he then viewed as the "typical classical theory." In this model, there are two production processes that are represented by two production functions. Each production function contains only one factor, labor, which can be shifted at no cost from one sector to the other. There is a given relative price at which the consumption good can be exchanged for investment. This relative price is determined by the functional forms of the two production functions. The value of output or aggregate production is then the sum of the values of consumption and investment. Similarly, Santi K. Chakrabarti (1979) argues that Keynes’s theories should be studied in a two-sector framework and reformulated in terms of wage units.

Hicks’s model is concerned with short periods of time, because the quantity of physical capital available in the economy is taken as fixed. James E. Meade (1961) and Hirofumi Uzawa (1963) provide early analyses of the dynamics of two-sector models examining consumption and capital. Another two-sector model is considered by James Tobin (1965). In Tobin’s model, one sector produces the physical good, which can be consumed or invested. The other sector is a monetary asset issued by the government to finance public spending. The creation of money affects the capital-labor ratio in the economy. This ratio varies with the rate of inflation. In this second group of models the economy is assumed to save a fixed proportion of income. A further step is taken by Duncan K. Foley and Miguel Sidrauski (1971), who postulate a non-constant saving rate—according to them, the propensity to save may depend on the interest rate and total income. Still, this saving function is ad hoc in that it is not derived as the solution of a behavioral maximization process. The formulation of the optimal amount of savings was posed by Frank P. Ramsey (1928) as a one-sector planning problem. This approach was later extended to two-sector models. Thus, at each moment in time a representative individual may decide on the level of consumption and investment, and the optimal amounts of production in the two sectors.

There are three main types of production functions that have been used to describe the production processes in two-sector models. The first models used von Neumann linear production function in which output is proportional to the amount of labor and capital used. A