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GENETICS—THE SCIENCE OF HEREDITY

BY JOHN PFEIFFER



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The Golden Jubilee of Genetics

THE year 1950 marked the 50th year of Genetics, the study of heredity. In 1900, the basic principles of Genetics established by Gregor Johann Mendel were "rediscovered" by biologists working independently in Holland, Austria, and Germany.

Mendel's work is the keystone of modern Genetics. In 1950, the Genetics Society of America staged a Golden Jubilee of Genetics, featuring scientific meetings in which a group of internationally distinguished geneticists participated.

The publications committee for the Golden Jubilee of Genetics cooperated in the preparation of this pamphlet as a part of its activities designed to inform the general public of the contributions which Genetics has made to scientific progress and human welfare.

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GENETICS— THE SCIENCE OF HEREDITY

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By JOHN PFEIFFER

THE nation's cornfields provide a spectacular example of advances in modern agriculture. The rows of corn on an old-style farm are as oddly assorted and "undisciplined" as any group of raw recruits reporting for their first military drill. Some of the stalks are tall and slender, others are short and stocky, still others stoop over or stand upright. The unkempt appearance of these irregulars means extra work for the farmer. The ears are usually harvested by hand. If one man can pick 100 bushels a day, he is doing better than average.

This is "mongrel" corn. Its original ancestors were first cultivated thousands of years ago in North or Central America, but the details of its family tree are buried in the past. For centuries corn had been allowed to fertilize at random in open fields. Since wind-blown pollen might come from any one of hundreds of neighboring plants, the ears that ultimately develop are of mixed and—even more important—unknown heritage.

But the pedigrees of the plants used in Iowa, Illinois and other corn-belt states are known back to their great-great grandparents and even further into the past. All the stalks are firm,

This pamphlet, written by John Pfeiffer and illustrated by Ralph Graeter, was prepared with the cooperation of Professor L. C. Dunn, Co-Chairman of the Golden Jubilee Committee of the Genetics Society of America.

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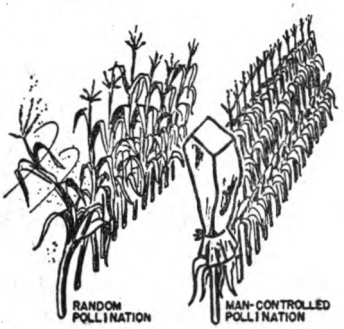
upright and of uniform tallness. The ears all grow waist-high (in unpedigreed corn they grow high and low on the stalks), and can be harvested by machine at a rate of 1,000 bushels a day. Not only that, but the ears are larger, more nourishing, and contain more kernels than those from plants of uncertain parentage. The new hybrid plants yield nearly a third more corn per acre.



Hybrid corn is the offspring of parent plants carefully selected for desirable hereditary traits. It has completely revolutionized the farming of one of our most important crops. In 1932 such made-to-order corn was a laboratory curiosity; today it accounts for more than 75 per cent of the total crop in the United States.

In 1932 American farmers harvested nearly three billion bushels of corn. Fourteen years later production had increased by 300,000,000 bushels, and the tremendous crop required 23,000,000 *fewer* acres of land. This farmland was freed for other crops and soil-conservation measures. The extra hybrid corn produced during the war years alone was worth a conservatively estimated $2,000,000,000—the total cost of the Manhattan Project.

This and many other advances in agriculture and medicine have resulted from research in genetics, the science of heredity. Underlying similarities have been discovered in a wide variety of apparently unrelated living things—from molds and plants to human beings—and these discoveries have been put to work to improve your living standards.

Our understanding of the basic laws of heredity has been used to improve the health and welfare of the American people—and of people in other nations as well. The creation of hybrid plants like corn, and hybrid animals that produce more meat, is a vital part of the drive to provide adequately for the growing population of the earth. Because of new findings in genetics we can now supply large quantities of food to a hungry world and still have enough for ourselves.

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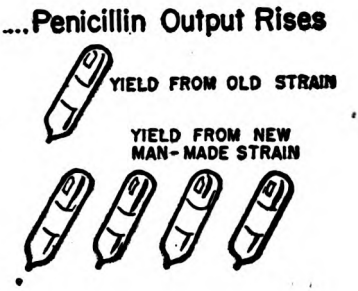
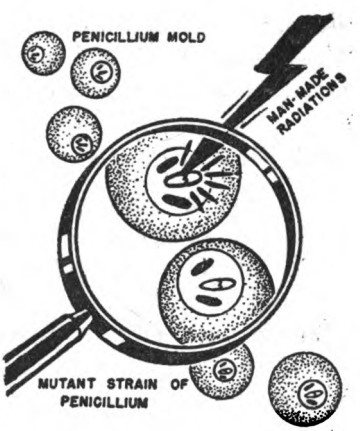
Genetics studies problems as ancient as human curiosity. Why do certain traits run in families? What determines whether your child will be a boy or a girl? What can we do about inherited diseases? These are only a few of the questions which geneticists are answering, or have already answered. The science of heredity has been of primary importance in the campaign to prevent disease, one of the most ambitious goals of modern medicine.



More Penicillin

Let us take an example. The United States produces penicillin for many foreign countries, as well as for its own citizens. Your doctor has enough penicillin to meet all emergencies from a sudden strep sore throat to an attack of a germ-caused disease of the heart valves, which was 100 per cent fatal less than a generation ago. Today's abundant supply may be traced, in large part, to an experiment conducted during the war by a biologist in New York.



The scientist set out to make an entirely new breed of penicillin-producing mold, a microorganism that would yield larger amounts of the drug. He reached his goal by using X-rays to change the heredity of the molds. Thousands of microbes were bombarded with carefully regulated doses of the rays. Many of the offspring were unchanged. But a few produced surprisingly large quantities of the drug, and their descendants were bred under laboratory conditions that were rigidly controlled.

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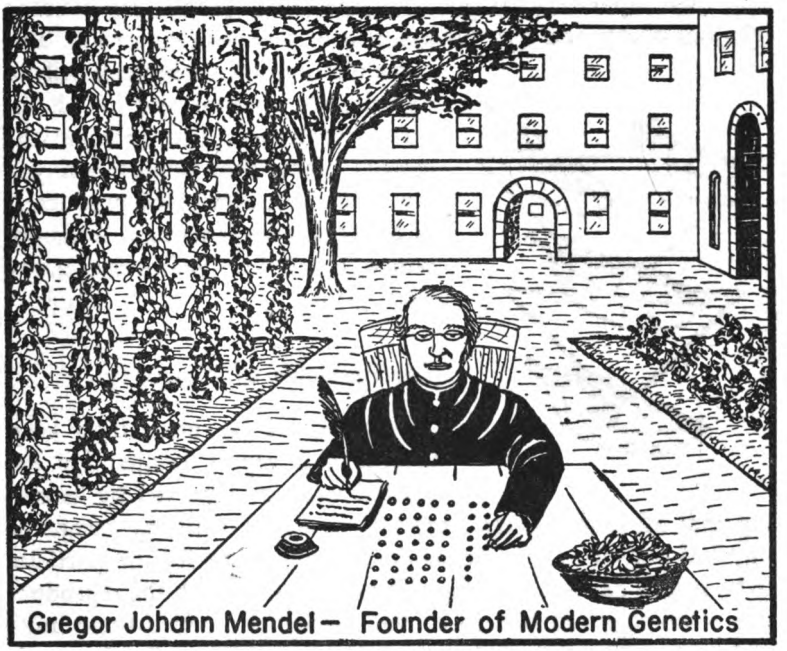
Similar effects have been studied among human beings. For example, children of immigrants living in the United States are generally taller than their parents, probably because they receive a better balanced diet and better medical care. Although such


Gregor Johann Mendel— Founder of Modern Genetics

differences may occur, they are restricted to a range of a few inches. Arguments as to which is more important, heredity or environment, have little meaning in the light of modern genetics. All organisms from peas to people are shaped by a subtle interplay between the two.

The Laws of Heredity

Continuing his work, Mendel crossed dwarf and tall peas. No matter how he did it, "tall" pollen with "dwarf" egg or vice versa, the mixed or hybrid offspring of the first generation were all tall. The dwarf character had disappeared. But when the

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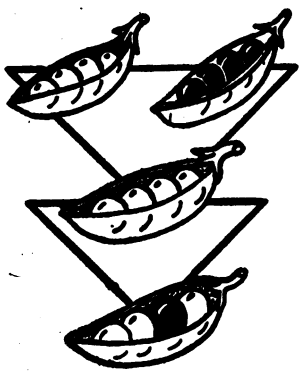
eggs and pollen of this crop were used to obtain fertilized seeds and the seeds were planted, the missing trait turned up again in the second generation. But it always turned up in a regular and predictable manner.

Mendel collected 1,064 grandchildren of the original plants and then separated the tall from the dwarf plants. He counted 787 tall plants and 277 dwarfs, nearly a three-to-one ratio. The same distribution occurred in all his experiments on peas and for all the traits he studied. For example, he crossed plants that always had yellow seeds with green-seed producers; of 8,023 second-generation seeds obtained, 6,022 were yellow and 2,001 were green.



The Particles of Heredity

Mendel did far more than keep records and report results. He explained what he observed by assuming that all living things transmit hereditary traits by means of physical particles. This means that the only way for the particles to be passed on to succeeding generations is through the reproductive cells—eggs and pollen—of the parents. He called these units of heredity "formative elements" instead of "genes" (the modern term), but otherwise his explanation was amazingly up to date.

An egg from a pure-bred tall pea plant contains a "tall" gene, and so does the pollen. When the two unite, the fertilized egg naturally develops into a tall plant, because it obtains the same heredity from each of its parents. The egg then splits into a pair of new cells each containing duplicates of the two original tall genes, and all subsequent cells also contain two tall genes. The full-grown offspring is thus composed of double-gene cells—with one exception. Its eggs and pollen have only one tall gene each, and inbreeding will continue to produce tall plants. Similarly, if dwarf-strain eggs unite with dwarf-strain pollen, they "breed true," yielding only undersized offspring with two dwarf genes.

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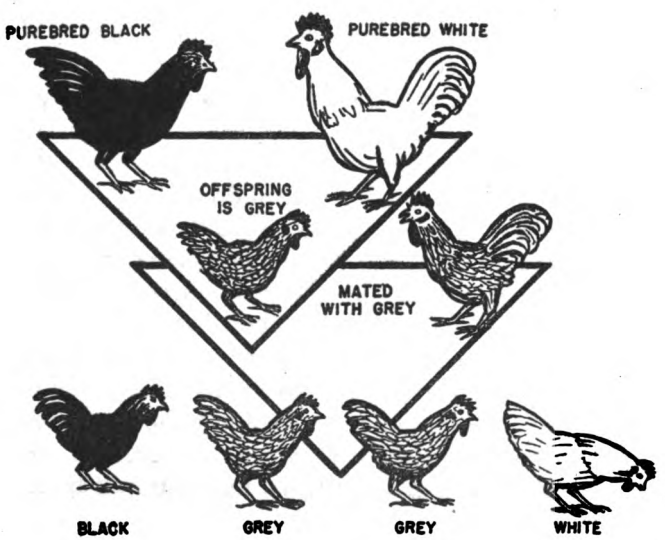
Dominant and Recessive Genes

What happens when pure-bred strains are crossed? The two types of hereditary particles are mixed. All the fertilized eggs of the first generation contain a dwarf gene from one parent and a tall gene from the other. The eggs develop into hybrids with a dwarf-tall heredity and, since the dwarf trait disappears, the tall gene is called "dominant." This is simply another way of saying that it "overpowers" the dwarf gene. If a fertilized egg has one tall gene, it will develop into a tall plant—whatever the gene from the pollen happens to be. But dwarf genes are "recessive" which means that two of them must be present in a fertilized egg to yield dwarf offspring.

When the hybrid forms its sex cells—eggs and pollen—it is found that the tall genes and dwarf genes have not mixed; each has remained intact and each sex cell gets either one or the other, never both. Thus since the sex cells of the hybrid are half "tall"

The 3to1 Ratio Demonstrated



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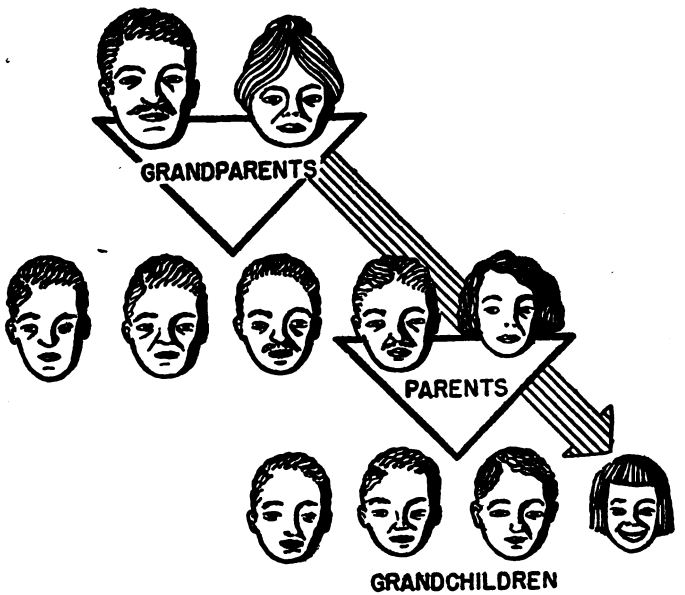
Not all traits are inherited according to this simple ratio because many of them depend on the interaction of more than one set of genes. But even in cases where the exact ratios have



not yet been discovered the effects of dominant and recessive genes are evident. For example, curly hair is dominant over straight hair, brown eyes over blue or gray, freckles over unspotted skin, blonde or brunette hair over red hair, and some types of baldness over a normal growth of hair.

But you are more than simply the product of your genes. You can build up your strength by regular exercise or wear yourself to a shadow from overwork. And you can learn. Intelligence is inherited, if you mean the normal functioning of a healthy brain. Genes certainly have something to do with laying down the elementary structure of the nervous system. But experience and training play the most important role in guiding its advanced development. A baby can cry at birth, but learning the multiplication tables and playing the piano come later, and produce new structures in the brain.

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Where Are Genes?

Genes are protein molecules about five millionths of an inch long. They are difficult to get at, not only because of their small size, but also because they lie buried deep in living cells. The heredity-transmitting units do not drift about the cell, but come

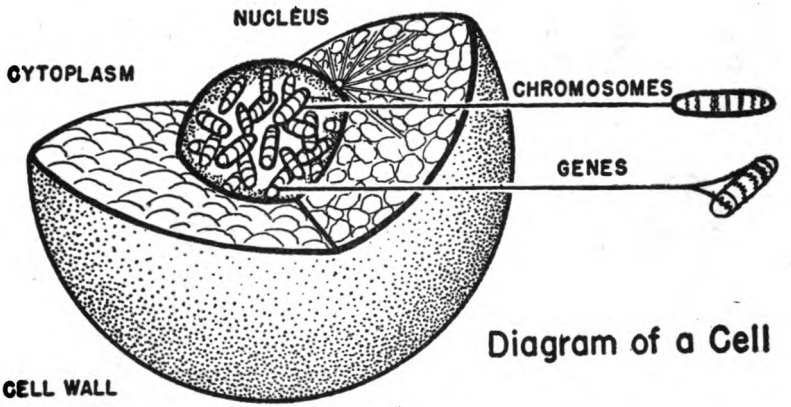

Diagram of a Cell

firmly enclosed in "sausage casings." Since these containers absorb certain dyes, they are called chromosomes (Greek for "colored bodies").

The largest chromosomes can be seen under the microscope in the central nucleus of the cell. They contain many bands of darker material, and genes are located along these bands. Genes have definite sites, and hundreds have been "mapped" in the chromosomes of corn and fruit flies, each band being identified with a unique hereditary trait. Some human genes have also been charted, although not in such detail.

How You Get Your Genes

The cells of plants and animals have a number of gene-concontaining chromosomes which is characteristic of the particular species. It ranges from two in a type of roundworm to more than 200 in certain varieties of crayfish. We have 48 chromosomes. All you inherit is embodied in this quota which you receive from your parents, half from your father and half from your mother.

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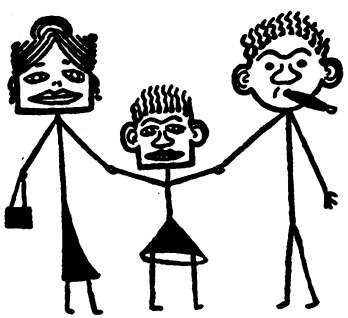
When a tadpole-shaped sperm penetrates an egg, each of its chromosomes joins with one of the chromosomes in the egg to produce 24 "mated" pairs. Because of this pairing, there are two genes for practically all inherited traits. A complete set of human chromosomes contains an estimated 30,000 genes, and many combinations may occur depending on how they line up together. The combination that is you was one of the 281,474,976,710,656 possible types your parents could have produced.

When the fertilized egg divides, the chromosomes also divide so that the two resulting cells each contains a full set. This process is repeated with every division, as an egg about the size of a grain of sand multiplies into an organism of 26,000,000,000,000 cells—a newborn baby. Every cell in the body contains 48 chromosomes, that is, all but the sperm and egg. These contain a half share for the next generation. In other words, half of your child's heredity comes from you and half from your husband or wife.

What Genes Do

Genes are biological architects. Their task is to use material obtained from the environment and build the body according to hereditary blueprints. Every cell in your body contains a full "staff" of 30,000 genes, but which ones work most actively depends on where the cell is located. If your specifications call for brown eyes, a dark complexion, an aquiline nose, and a heavy frame, your genes see to it that the job is done properly. They direct the work of many "craftsmen," including the cells that produce pigments and bone-forming calcium. The parts of the body are so complex, however, that one gene is rarely enough to determine a single trait. At least 150 different genes are required for the construction of the eyes alone, and this total does not include the ones that control eye color.



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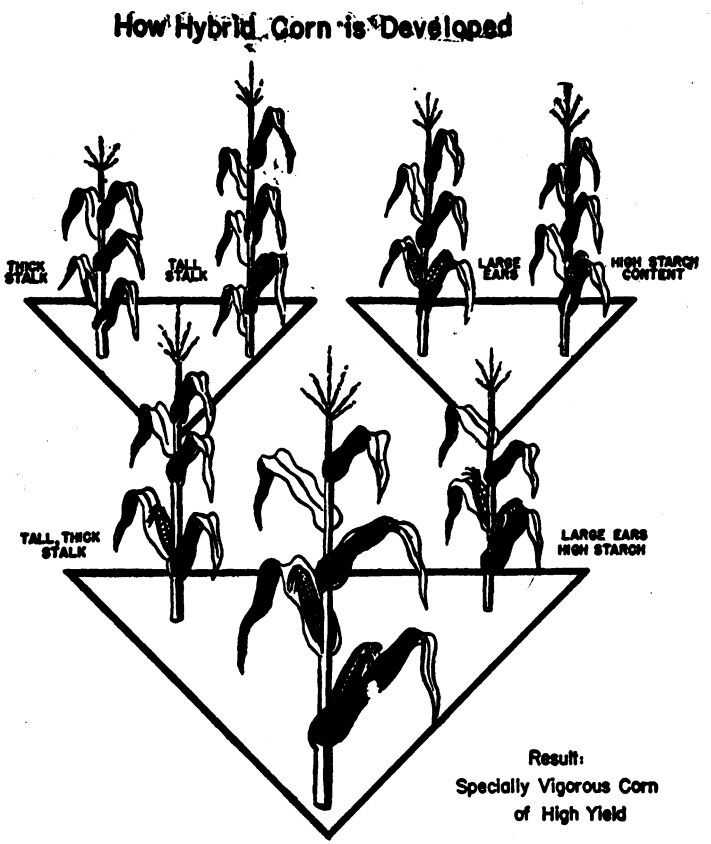
erations until a pure strain was obtained. It takes about six to seven years to produce such strains, but that was only the beginning. Once desirable traits were separated from the original mixed-heredity plants, the job was to "put the pieces together" in a new way and create corn with as many dominant genes as possible.

A pure strain yielding large ears, for example, was crossed with a pure strain that produced tall stalks. This hybrid was crossed with another having high starch content and strong stalks that wouldn't break in storms. The final result was complex hybrids, "packages" of carefully selected dominant genes. The same sort of breeding tests has led to the creation of many plants, in-



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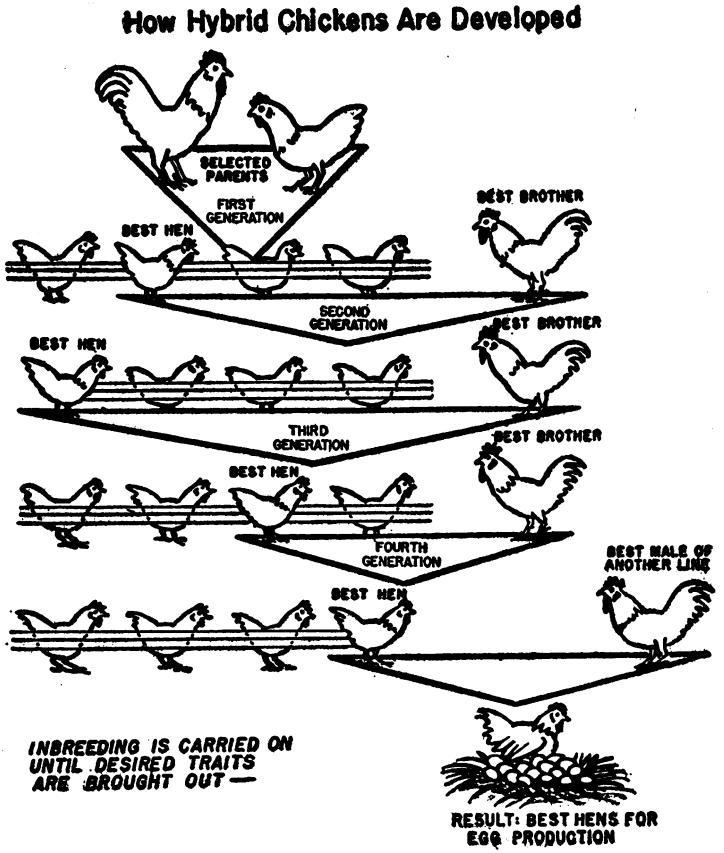

Genetics in Action

The science of heredity has been used in many other ways. It has brought a new and far broader understanding of important facts about marriage and reproduction. Before Mendel's work, the underlying reason for laws against marriages between close relatives was not understood. Scientists did not know what determines whether a child will be a boy or a girl, why identical twins were identical, or why certain diseases seemed to afflict men and not women. Practical applications include advances in the war against disease and in breeding new varieties of plants and animals for the nation's farms.

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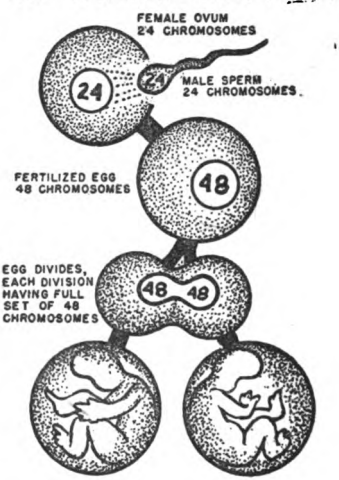
"Identical" twins, however, are always of the same sex and are often mistaken for each other throughout their lives. They come from a single egg. Since this means identical twins have identical sets of genes, they are of special interest in the study of heredity. Detailed life histories of such twins furnish important clues to the interworkings of heredity and environment.

How Identical Twins Occur



For example, studies of large numbers of identical twins reveal that if one member of a given pair has tuberculosis, the other twin has an extra-large chance of getting the same disease. But the disease does not always strike both twins, which is another indication of the fact that environment may have a modifying effect on heredity.

On the other hand, the power of heredity may express itself dramatically in identical twins, even though they are brought up in different environments. Geneticists recently described the case of a 22-year-old farmer who refused to eat his lunch one day because he thought his mother was trying to kill him and had poisoned the food. He ran off through the fields, and wasn't found until the end of the day. Gradually he became more and more deranged. Finally, he was committed to a mental institution as a victim of schizophrenia.

Two weeks later another patient, who had been working in another state for the past five years, was admitted to the same hospital suffering from the same disease. He had run away from his aunt. It turned out that he was the first patient's identical twin!

The "Rh" Factor

For many years a mysterious ailment was killing infants in the nation's maternity wards. Most of the victims were born dead; some died a few days after birth. Even in the rare cases where babies survived, the hereditary disease produced perma-

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