COUNTING AND MEASURING

* In trying to get to grips with the basics of genetics, Mendel had deliberately chosen to work on simple characteristics that varied in an "either/or" fashion. Plants had either yellow seeds or green seeds, pink flowers or white flowers, for example. There were no intermediate types, and the offspring always resembled one of the two parents. But most characters vary in a more gradual and continuous fashion.

VARIATION

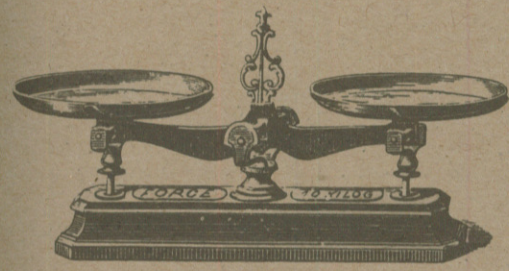
The difference between discrete and continuous variation is essentially the difference between counting and measuring. Analyzing the inheritance of discrete characteristics relies on counting the number of individuals of each distinct type, whereas analyzing the inheritance of continuous characteristics relies on measuring individuals.

TALL OR SHORT

height is a continuous characteristic

* In humans, most characteristics can't be divided up into a small number of DISCRETE (DISTINCTLY DEFINED OR SEPARATE) alternatives. Think of height, weight, and skin color, for example. These all display a much more continuous spectrum of variation.

* To the early geneticists, the inheritance of such "CONTINUOUS" CHARACTERISTICS seemed to have little to do with the simple rules laid out by Mendel. Tallish fathers and shortish mothers invariably produced children of intermediate height. It therefore appeared, superficially at least, that inheritance was a process of blending. But the blending idea could not explain how parents of a medium height were able to produce children who were tall or short.



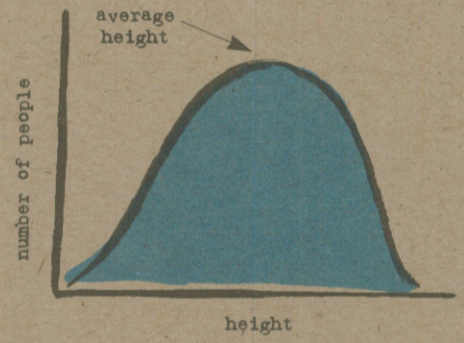
offspring may inherit a balance of parental characteristics

MANY GENES

* *Nowadays, biologists recognize that "continuous" characteristics are controlled by genes at many different loci.* Though they may sometimes give the impression of blending, each one of the gene pairs behaves in a similar way to the gene pair responsible for controlling pea shape. Skin color, for example, is influenced by at least four gene pairs. Each gene in a gene pair makes a contribution to the overall expression of the skin color, either in the lighter or darker direction—so that the skin color you inherit will be the sum of the effects of several separate genes.

The Bell Curve

If you took a random sample of people, measured all their heights, and then plotted the number of people at each height, the resulting frequency distribution would resemble a bell-shaped curve called a normal distribution. The population would display a continuous range of heights, though most people would cluster around the average. Most human characteristics display a similar pattern of variation.



frequency distribution of heights in the human population

uneducated workers were believed to have a low IQ

THE STAIN OF EUGENICS

*** The study of human inheritance was established by Francis Galton. But Galton's interest had as much to do with social prejudice as it did with hard science. Galton was obsessed with the biological improvement of the human race. For many of Galton's supporters, the rediscovery of Mendel's laws seemed to give scientific credibility to their racist and bigoted views. Genetics was about to enter the bleakest period of its short history.**

IQ Tests

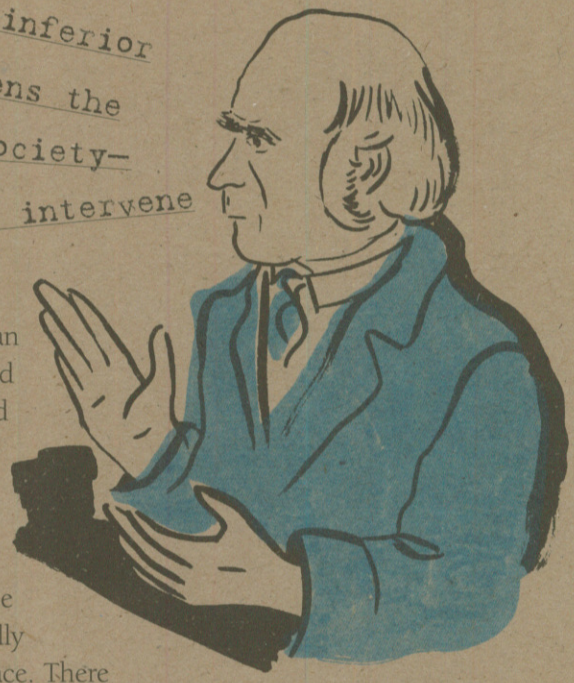
The IQ (Intelligence Quotient) test was initially established as a way of discriminating between "able" and "unable" people. Because intelligence was believed to be an innate genetic quality, early versions of the test conveniently overlooked the influence of education. This had the effect of highlighting the apparently low intelligence of the poorer classes, for whom quality education was a pipe dream.

SLUMMING IT

* In the 19th century, divisions between rich and poor had been exacerbated by the mass urbanization that accompanied the industrial revolution. Slums had become endemic to many of the world's largest cities. To those with wealth and status, poverty was seen as an expression of lesser ability. Slums were considered breeding grounds for the worst characteristics humanity had to offer.

* After conducting a survey of prominent and wealthy families, Galton claimed in his book *Hereditary Genius* (1869) that ability was inherited—able fathers had able sons—and could not be enhanced by education. Galton was the first to suggest that the proliferation of the poor and underprivileged was getting out of hand. He believed that the uncontrolled spread of an "inferior" race threatened the future of society, and that it was time for the state to intervene.

the inferior race threatens the future of society— the state must intervene



* In 1883, he coined the term "EUGENICS" to describe the practice of biologically improving the human race. There were two ways in which he envisioned this could be done. First, positive eugenics would encourage the professional classes to have more children by granting income tax relief for each child born. Second, and more controversial, negative eugenics aimed to physically prevent those of lesser ability from having children.

SCIENCE GONE MAD

* Initially Galton's proposals received a cool reception. But for many who shared his influence and wealth the reemergence of Mendelism added scientific weight to his arguments. Criminality, mental illness, and low intelligence were seen as products of specific genes—and only by preventing inferior races from breeding would these genes be removed from circulation.

FRANCIS GALTON

Francis Galton (1822–1911) founded the Laboratory for National Eugenics (now the Galton Laboratory) at University College London, the first human genetics department in the world. His often eccentric career also included the scientific study of fingerprints, statistical tests on the efficacy of prayer, and the publication of a human-beauty map of the British Isles.

any disability was a mark of "inferiority"

BLAZING A TRAIL OF BIGOTRY

*** The first eugenics legislation was introduced in the early 20th century, and concentrated mainly on negative eugenics. Its ramifications, which were felt throughout Europe and the U.S., culminated violently and abruptly in the comprehensive sterilization programs of Nazi Germany.**

INFERIORITY COMPLEX

* Concerned that uncontrolled immigration of "racially inferior types" was threatening the genetic health of Americans, many states imposed quotas on the number of immigrants allowed to settle. It is a terrible irony that by the 1930s, Eastern Europeans— one of the primary targets of US prejudice— were seeking new homes in order to escape from the even more extreme racist program orchestrated by the Nazis.

Sterilization of inferior types

Many U.S. states passed legislation requiring the incarceration and/or sterilization of so-called inferior types. This was an umbrella term that included the mentally ill or insane, people of low intelligence, and criminals. But prejudice was given a free reign, and in some states the inferior label was extended to include homosexuals and Communists! By the 1930s, at least 20,000 people had been sterilized in the U.S.

PHONEY SCIENCE

* Adolf Hitler's obsession with racial purity and the Aryan ideal took the prejudice and bigotry of eugenics to a grim conclusion. Anyone with any form of mental or physical handicap was

Adolf Hitler

institutionalized, man, woman, or child. And in Nazi Germany incarceration usually meant extermination, rather than sterilization. Hitler may have occasionally dressed his policies in the language of science, but the "science" of eugenics was now no more than a sham.

eugenics was an excuse to persecute people of low intelligence

DIRTY POLITICS

* To assume that all human traits were exclusively controlled by specific genes that could be artificially selected was not only deeply simplistic, but also untrue. Today, eugenics remains a blemish on the history of genetics. It was a political movement, with little or no grounding in science. The study of human genetics fell into a long period of decline because scientists became reluctant to associate themselves with a subject tarnished by controversy and human suffering.

"America must be kept American. Biological laws show that Nordics deteriorate when mixed with other races."

CALVIN COOLIDGE, PRESIDENT OF THE UNITED STATES 1923-29

A ONE-WAY TICKET

*** Although hereditary determinism was all the rage in the West, in the Soviet Union of the 1930s its political antithesis—Lamarckism—was the dominant force. This time it was biologists who bore the brunt of political ideology. Mendelism was perceived as a bourgeois capitalist conspiracy against Marxism, and any Soviet scientists sympathetic to Mendelian genetics were given a one-way ticket to Siberia.**

wheat was a vital crop in the Soviet Union

Mendelian Martyr

In 1940 **Nikolai Vavilov** *(1887–1943), one of the Soviet Union's best Mendelian geneticists, was arrested and interrogated for 1,700 hours. In a five-minute trial, he was found guilty of crimes against the state. He died in a prison camp in 1943.*

MARXIST PHILOSOPHY

* Stalin despised the idea that even pea shape, let alone any human characteristic, was determined by genes. Lamarckian inheritance sat much more comfortably alongside the Marxist philosophy, which emphasized the importance of the environment in shaping the individual and society.

* Stalin had found a close political ally in the Russian biologist **Trofim Lysenko**. Lysenko had made a name for himself through his experiments on the "vernalization" of wheat—a process in which seeds are frozen so that they will germinate earlier the following spring. Although vernalization was already well known in the West, Lysenko claimed that the effect was inherited, in a Lamarckian manner. If true, this would have had immense agricultural value in areas where the growing seasons were particularly short.

SHORT, SHARP SHOCK

* Lysenko pledged to offer scientific short-cuts to the perennial problem of food shortages. By exposing crops to cold shocks, for example, he claimed that new and hardy ice-resistant crops would evolve.

snowflakes

As the newly instated Director of Agriculture, Lysenko gained sufficient political and scientific influence to impose Lamarckian inheritance wholesale on Russian biology. Geneticists were given a stark choice: either deny their allegiance to Mendelism and its capitalist subplot or face imprisonment in a Siberian labor camp.

"We shall go to the pyre, we shall burn but we shall not renounce our convictions."

NIKOLAI VAVILOV

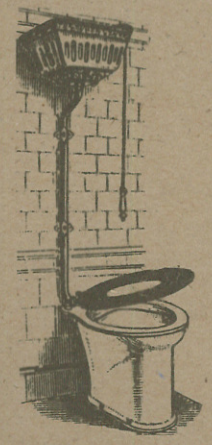
Lysenko claimed he could protect plants from cold weather

Lysenko's promise

Lysenko's promise to revolutionize Soviet agriculture eventually came to nothing. But not before he had managed to purge Russia of its best geneticists. His ideas, rooted in political ideology rather than science, effectively cut the Soviet Union off from the scientific advances being made in the West. Only in the 1950s did Soviet genetics begin to return to normality.

FROM YELLOW TO BLACK, FROM GENES TO ENZYMES

*** The first hint that genes and enzymes—protein catalysts that increase the rate of chemical reactions in the body—were related to each other dates back to a breakthrough made by the English physician Archibald Garrod in 1908. Garrod discovered that an inherited disease was caused by a block in a chemical reaction within the body and hypothesized that a functioning gene produces a specific enzyme.**



the evidence is in the can

Essential Acids

Not all the amino acids needed to make proteins can be synthesized by the body itself. About eight of the 20 or so amino acids that the body needs must be provided in the diet. These are known as essential amino acids.

BLACK STUFF

* Garrod had been fascinated by the rare genetic disease ALKAPTONURIA, whose inheritance followed a simple Mendelian pattern. Though the disease is not serious, its symptoms are striking. After eating certain types of food, affected persons produce urine that turns black as soon as it is exposed to the air. The black color is due to the presence of homogentisic acid, a chemical intermediate produced in the metabolic breakdown of the amino acid tyrosine. In persons unaffected by the disease, homogentisic acid is further broken down, and eventually converted to carbon dioxide and water.

Garrod in his laboratory

essential amino acids are provided in diet

ENZYME ABSENCE

* Garrod suggested that alkaptonuria was caused by the absence of a specific enzyme. The missing enzyme would mean that the normal sequence of chemical reactions in the breakdown of tyrosine would be blocked, resulting in the accumulation of homogentisic acid in the blood, tissues, and urine. It was later confirmed that people affected by alkaptonuria do in fact lack the enzyme needed to break down homogentisic acid.

* ***Garrod had shown that a mutation in a particular gene produced a defect in a particular enzyme—which led, not unnaturally, to his conclusion that a functioning gene specifies an enzyme that enables a chemical reaction to take place in the body.***

* His work was later confirmed by the American scientists George Beadle and E.L. Tatum in the early 1940s.

NEGLECTED BREAKTHROUGH

Archibald Garrod (1857–1936) was the first to show a connection between an altered gene and an enzyme—one of the fundamentals of genetics. His work, however, like Mendel's, went pretty much unnoticed for almost 30 years.