History of Statistics 5.
Statistics moves from the physical sciences to the social sciences – Adolphe Quetelet (1796-1874)

Adolphe Quetelet

Many notes on the history of statistics describe some person's specific *mathematical* contribution. Examples include Pascal's publication about the triangle of binomial coefficients, or De Moivre's derivation of the formula for the normal curve, but one of the most influential people in the history of statistics didn't do any such thing. **Adolphe Quetelet** (born in 1795) was a generalist, who published almost no mathematical papers, but whose influence in the **application of statistics to social topics** was groundbreaking and extraordinarily influential. To understand his work it is useful to review what mathematicians were working on when Quetelet was a young man.

Until about 1820, the development of the mathematical foundations of statistical methodology was deeply connected to the physical sciences, especially astronomy. A huge amount of energy went into understanding and describing the orbits of planets and asteroids. The goal was to model such orbits, but there were a limited number of data points for any celestial object, and the measurements themselves were not nearly as precise as is possible today.

One fundamental theoretical issue was *how to combine the measurements* for any one phenomenon, such as the position of a planet at a given time. For example, what theoretical justification might there be for choosing the mean rather than the median of a set of observations? Should all the measurements be used or only the ones that seem most reliable? A second theoretical problem was how to describe the accuracy of a model when the data, influenced by random measurement error, did not fit the model perfectly. Major advances were being made in topics such as finding the best-fitting line or curve. The primary deep mathematical result was the *principle of least squares*. The "best" model was the one that yielded the smallest possible sum of the *squares* of the deviations of the data from the model. Mathematicians who contributed to this work include Legendre, Laplace, and Gauss.

Between about 1800 and 1820 these mathematicians published a number of papers making stronger and stronger arguments for the principle of least squares, gradually using it not only to find the best fitting model, but also to give a probabilistic interpretation of how well the model worked.

Here are a few indications that the principle of least squares was becoming *the* way to fit models to data.

In June of 1801 data were published by an Italian astronomer about the location of a new moving object in the sky. The object had disappeared out of view behind the sun. Gauss analyzed these data and in September published a paper that predicted where it would be when it became visible again at the end of December. His prediction was accurate enough (and better than the predictions of other astronomers) to lead to the discovery of Ceres, the first celestial object called an asteroid. Gauss did not say how he did the calculations, but it seems evident that he used a version of the least squares principle.

In 1805 Legendre published *Nouvelles méthodes pour la détermination des orbites des comètes*, in which he proposed:

> Of all the principles that can be proposed for this purpose. I think there is none more general, more exact, or easier to apply, than that which we have used in this work; it consists of making the sum of the squares of the errors a *minimum*. By this method, a kind of equilibrium is established among the errors which, since it prevents the extremes from dominating, is appropriate for revealing the state of the system which most nearly approaches the truth.

In 1809 Gauss published *The Theory of the Motion of Heavenly Bodies Moving about the Sun in Conic Sections.* In this work he built on Legendre's least square ideas but *specifically used the normal distribution as a model for measurement error.*

A year later Laplace published his work on what is now called the *central limit theorem*, which showed that the *means* of a large number of measurements of something will be approximately normally distributed. The two major issues, combining measurements and assigning probabilities, were becoming linked in the development of the principle of least squares.

Deep questions often motivated these investigations. Why do the objects in the sky remain in stable orbits? If they didn't, then the attempt to find the ideal model for their paths made no sense in the first place. The statistical analysis provided evidence that even with occasional random perturbations or "bumps," the whole planetary system tended to keep to its "true" arrangement.

Quetelet and the concept of "The Average Man."

Adolphe Quetelet came of age in this era of tremendous scientific achievement and of political turmoil. Quetelet was born in 1795 in Ghent, which was then part of the French Republic. After the defeat of Napoleon in 1815 it became the southern part of the newly unified United Kingdom of the Netherlands. In 1817, the new king, William I, founded the University of Ghent to beef up intellectual capacity, especially compared to France, and in 1819 Quetelet received the first doctorate of science awarded by the university. His dissertation was on the geometry of certain curves that were useful in understanding optics. He immediately sought out and obtained funding to build the Royal Observatory in Ghent. That he achieved this at age 26 already suggests an impressive, almost charismatic personality. (In 1830, the Netherlands separated and the southern part became Belgium. Quetelet is now identified as a Belgian scientist.)

To learn about astronomy, Quetelet visited the leading scientists of Paris. It was there that he became acquainted with the work of Legendre, Laplace, and Fourier, and their use of probability and statistics in astronomy. He developed a passion for applying these mathematical tools to areas outside the physical sciences. In that sense he was the *founder of quantitative sociology*, thinking that the best understanding of human society needed to be data-based. In 1835 he published *Sur l'Homme et le Développement de Ses Facultés* (*A Treatise On Man And The Development Of His Faculties*.) In this extraordinarily influential book he emphasized his concept of ***"the average man."*** (In the original French, ***l'homme moyen***.) We have been dealing with the consequences of Quetelet's construct of the average man ever since.

Quetelet's conccern in the social sciences was the description of "stability" in human affairs rather than planetary orbits. For example, why was the crime rate essentially the same year after year in a given location? Here are three quotations and a chart from the introductory chapter of his book.

This remarkable constancy with which the same crimes appear annually in the same order, drawing down on their perpetrators the same punishments, in the same proportions, is a singular fact, which we owe to the statistics of the tribunals.

Sad condition of humanity! We might even predict annually how many individuals will stain their hands with the blood of their fellow-men, how many will be forgers, how many will deal in poison, pretty nearly in the same way as we may foretell the annual births and deaths.

Society includes within itself the germs of all the crimes committed, and at the same time the necessary facilities for their development. It is the social state, in some measure, which prepares these crimes, and the criminal is merely the instrument to execute them.

*** The following is the result of the reports of criminal justice in France, &c. :—**

	1826.	1827.	1828.	1829.	1830.	1831.
Murders in general, -	241	234	227	231	205	266
Gun and pistol, - -	56	64	60	61	57	88
Sabre, sword, stiletto, poniard, dagger, &c.,	15	7	8	7	12	30
Knife, - - - - - - -	39	40	34	46	44	34
Cudgels, cane, &c., -	23	28	31	24	12	21
Stones, - - - - - - -	20	20	21	21	11	9
Cutting, stabbing, and bruising instruments,	35	40	42	45	46	49
Strangulations, - - -	2	5	2	2	2	4
By precipitating and drowning, - - - -	6	16	6	1	4	3
Kicks and blows with the fist, - - - - -	28	12	21	23	17	26
Fire, - - - - - - - -	..	1	..	1	..	..
Unknown, - - - -	17	1	2	..	2	2

Because he was the first to look for such patterns of social stability, many of his discoveries were surprising. It was not a common understanding then, as it is now, that something like suicide, which was clearly the result of an individual decision, could in the aggregate display a consistent pattern.

The previous quotation makes it clear that Quetelet blames society as a whole rather than individuals (or the intervention of God) for root causes of crime. He saw criminal individuals as "perturbations" or deviations from the "true" model of the average man *(l'homme moyen).*

> This determination of the average man is not merely a matter of speculative curiosity; … The average man, indeed, is in a nation what the centre of gravity is in a body ; it is by having that central point in view that we arrive at the apprehension of all the phenomena of equilibrium and motion…

Quetelet realized that though the stability of crime rates, suicide rates, and other social phenomena was similar in form to a problem like the stability of a planetary orbit, the human problem was much more complex. There was no comparable Newtonian law of gravitation on which to base a theory. In the end, his plea was always for the collection of more data and the sensible description of the findings.

Quetelet's average man was the fictitious character all of whose characteristics were set equal to the mean of the observations of those characteristics. This is a very abstract interpretation of average. The concept of an average person is much slipperier than the concept of the average of a set of measurements of the distance to the moon. The average of the moon measurements is taken to be the true distance to the moon. Quetelet took the "average person" to be an ideal representative of his or her group. Importantly, Quetelet assumed that the distribution of the values for any given human characteristic was *normal. This was the first use of the normal curve as other than a description of scientific measurement errors*.

In addition to collecting social data such as crime or suicide rates which he believed reflected the *moral* qualities of a society, he also turned his attention to people's physical characteristics. His first major presentation of such data showed that a large set of published chest circumferences of Scottish soldiers followed a normal curve. In trying to come up with an overall rating of physical stature that was normally distributed Quetelet invented the **Body Mass Index (BMI**) which is (over)used now in studies of obesity. Quetelet did not have medical studies in mind; he just wanted a quantifiable variable that could be averaged in a society and then thought of as representative. Quetelet called this statistic an index of relative weight; it wasn't named BMI until 1972.

Quetelet took it that "the average man" varied among social groups, and he was interested to explain why that was so. Could he distinguish primary causes from just accidental variability? This proved too difficult given the level of sophistication of the statistical analysis he could do, and it is still one of the most vexing issues in statistics.

By the late 1800s, inspired by Quetelet's work, scholars in many fields were looking for the hidden "normal" laws that governed society and even physical science.

In History - Henry Buckle (1821-1862) Buckle was an influential English writer who proposed in his *History of Civilization in England* (1864) that there were general laws that governed human history. Buckle created the quantitative approach to history as Quetelet founded quantitative sociology. In his *History of Civilization* he quotes Quetelet on crime.

> M. Quetelet… states that "in every thing which concerns crime, the same numbers re-occur with a constancy which cannot be mistaken; and that this is the case even with those crimes which seem quite independent of human foresight…"

Such regularity led Buckle to a totally deterministic theory of history.

> Rejecting, then, the metaphysical dogma of free will, and the theological dogma of predestined events, we are driven to the conclusion that the actions of men, being determined solely by their antecedents, must have a character of uniformity, that is to say, must, under precisely the same circumstances, always issue in precisely the same results.

In Economics - Karl Marx (1818–1883) A much more important figure in history, economics, and politics was Karl Marx. Marx presented "laws" – or tendencies - that described economic change. Although less is known in detail about his debt to Quetelet, Marx was well acquainted with his work. For example, on the regulation of market prices by the prices of production he wrote that "the same domination of the regulating averages will be found here that Quetelet pointed out in the case of social phenomena."

In Social Reform - Florence Nightingale (1829-1910) Best known now as a nurse, Florence Nightingale was an influential statistician, administrator, and reformer of health systems. Quetelet, a friend, was an intellectual father figure for her. She read and carefully annotated his books. Unlike Buckle, Nightingale's passionate commitment to statistics was based on her faith in a God of order, who created a world that ran by law. In her memorial essay upon Quetelet's death she referred to using his discoveries to reveal "the road we must take if we are to discover the laws of God's government of His moral world."

In Psychology - Francis Galton (1822–1911) Galton was a cousin of Charles Darwin. He was particularly interested in characteristics of individuals that were inherited, where Darwin had stronger interest in what changed from one generation to the next. Galton was one of the first to try to measure intelligence. In the preface to his *Hereditary genius* (1869) Galton first describes how Quetelet used the normal curve to accurately describe physical characteristics of the body.

> The method I shall employ for discovering all this, is an application of the very curious theoretical law of "deviation from an average." … The law is an exceedingly general one. M. Quetelet, the Astronomer-Royal of Belgium, and the greatest authority on vital and social statistics, has largely used it in his inquiries.

And then he makes a major jump:

> Now, if this be the case with stature, then it will be true as regards every other physical feature – as circumference of head, size of brain, weight of grey matter, number of brain fibres, etc.; and thence, by a step on which no physiologist will hesitate, *as regards mental capacity.*

Galton's work marks the beginning of the use of statistics to measure intelligence and the whole enterprise of educational and psychological testing.

In Physics – James Maxwell (1831-1879) Maxwell was the most influential physicist of the 19^{th} century. He spearheaded the statistical treatment of the motion of molecules. It's unusual to see a mathematical approach move from the social sciences to the physical sciences. Maxwell had read Buckle's book.

> But the smallest portion of matter which we can subject to experiments consists of millions of molecules, not one of which ever becomes individually sensible to us. We cannot, therefore, ascertain the actual motion of any one of these molecules, so that we are obliged to abandon the strict historical method, and to adopt the statistical method of dealing with large groups of molecules. (Article in Nature magazine)
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> Hence those uniformities which we observe in our experiments with quantities of matter containing millions of millions of molecules are uniformities of the same kind as those explained by Laplace and wondered at by Buckle, arising from the slumping together of multitudes of cases, each of which is by no means uniform with the others. (In Campbell, page 439)

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