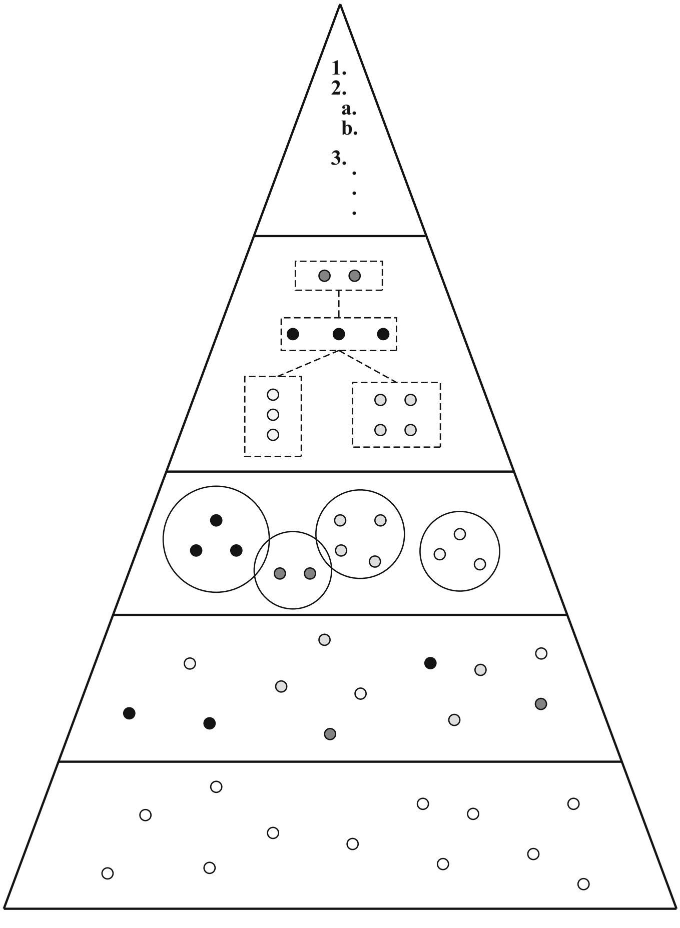

1.
2.
a.
b.
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*The stages of scientific evolution according to Dorothy Wrinch:*

1. *(bottom level): brute facts.*
2. *The facts are grouped into classes.*
3. *Theories link the classes and explain the facts.*
4. *The theories are organized logically.*
5. *The logical structure is axiomatized.*

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By Marjorie Senechal

# The Simplicity Postulate

## Marjorie Senechal

"Simplicity" conjures a string of synonyms, not necessarily synonymous with one another. *Ease*, as in the Simplicity® patterns I learned to sew with in junior high school (back then girls were taught to sew). *Unpretentious*, as in the Shaker song "Simple Gifts": "'Tis a gift to be simple, 'tis a gift to be free,/'Tis a gift to come down where we ought to be." *Minimal*, as in lifestyle. I think of my friend who would go to a shoe repair shop, hand her shoes to the proprietor, and sit down to wait. "Why don't you leave them and pick them up later?" I asked her. "Because these are my only shoes," she replied. "One pair is all I need." Easy, unpretentious, minimal: "simplicity" evokes these synonyms in math and science too, and there are more.

*Probable* is probably not on anyone's list today. Yet this synonym, proposed nearly a century ago, caused waves that still ripple. That *simplicity* = *probability* was the insight of two young Cambridge-pedigreed mathematicians, Dorothy Wrinch (1894–1976) and Harold Jeffreys (1891–1989). At the time, circa 1920, Wrinch was teaching mathematics at University College, London, and Jeffreys was working in the London Meteorological Office. She played tennis and piano, in much the same style. He was an avid cyclist and rode his bike everywhere into his 90s. She was sharp of mind, eye, and tongue and firm of opinion. He was taciturn, hard to talk to. Both were drawn to probability theory, a controversial subject at the time.

I knew Wrinch well in her last decade. I had just joined the Smith College mathematics department. She was a "retired" professor of physics. We met through our common interest in symmetry and crystals. She was an improbable character. After excelling in math at Girton College, she studied Russell and Whitehead's *Principia Mathematica* with Bertrand Russell himself; his enthusiasm for foundations failed to take root in her, but they remained friends. She taught mathematics briefly at

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University College and then at Oxford for 14 years. At the beginning of World War II, she emigrated to the United States. After a brief stint in the Johns Hopkins chemistry department, she was invited to Smith College to teach molecular biology for a year—the first course on this new subject anywhere. She stayed on as a *de facto* permanent visitor in the physics department. Visiting status left her free to follow the hunches of her restless mind, which had already blazed trails through mathematics, sociology, philosophy, seismology, protein chemistry, and crystallography. She crossed disciplinary boundaries easily, without glancing for oncoming trains [5].

But back to 1920. Wrinch had joined the Aristotelian Society, a London philosophical club of which Russell was a stalwart. Jeffreys attended as her guest. They were fascinated by a problem much discussed by the Aristotelians, a problem that straddled philosophy and psychology: scientific method. Not the feedback loop of hypothesis, experiment, and analysis we call scientific method today, but the question, "How do scientists choose between competing theories?" The question was live: the 1919 solar eclipse was to be the *demonstratio crucis* for Einstein's theory of gravitation. Yet Arthur Eddington, later Sir, who led the expedition to Africa to photograph it, had no doubt before he set forth that Einstein would prevail.

Like many in that rarified intellectual atmosphere, Wrinch and Jeffreys believed that every science will look like Euclid's *Elements* when it grows up. All sciences, they said, evolve from fact-gathering to axiomatizing; choosing among theories was a stage in the evolutionary process. In their time and for centuries before, the *Elements* was the second-most widely read book in England, after the Bible. Children learned his axioms, definitions, and propositions along with their Shakespeare. It wasn't just about the triangles. Euclid sharpened your mind, trained your logic. His clever proofs were the very model of argument. To master Euclid was to master the world, the world around you and beyond. "Nature and Nature's laws lay hid in night/God said, let Newton be, and all was light." And what did Newton's lamp look like? See for yourself in his *Principia Mathematica* [3]. "All human knowledge begins with intuitions," said Kant, "proceeds from there to concepts, and ends with ideas." Where do you think he got that?

Scientific method, then. A science begins with "brute facts," like (Wrinch's favorite example) the days that birds begin to sing in the spring. Next, the facts are grouped into classes. In the third stage, theories are proposed to link the classes. Scientists bow out at stage 4 and logicians enter, to clarify the logical structures of the theories and the relations between them. In the fifth and final stage of evolution, the pyramid is turned upside down. The science is recast in axioms and definitions from which the rest flows upward logically (see diagram on page 77).

For Wrinch and Jeffreys, steeped in Cambridge-style mathematical physics, theory meant natural law. A law, Henri Poincaré explained in *The Value of Science* [4], "is a constant relation between the phenomena of today and that of tomorrow, in a word, it is a differential equation." Thus Wrinch and Jeffrey's question narrowed to how scientists choose among equations that account for the same set of facts.

Is this logic, or is it psychology? Wrinch and Jeffreys argued that logic plays the larger role. Scientists choose the *simplest* equations, for starts: straight lines before quadratics, quadratics before cubics. And "simple" isn't fuzzy: simplicity can be measured. Differential equations are characterized by their order, degrees, and the absolute values of their coefficients. These are all positive integers, and their sum, said Wrinch and Jeffreys, is a measure of the equation's simplicity. The smaller the sum, the simpler the equation is; the greater the sum, the more complex.

So far, so good, but working scientists faced with competing differential equations don't tally these sums and choose accordingly. Nevertheless, they do opt for simplicity as a first approximation. Why? Is it because simple equations are easier to work with? Or because our minds construe nature in simple images? Or because nature is simple? None of these, said Wrinch and Jeffreys. Scientists opt for the simpler laws because they are more probable. They believe the simpler law is more likely to be true.

This Simplicity Postulate, as Wrinch and Jeffreys called it, didn't spread fast nor did it last long. Simplicity's role in scientific thought was not quite as simple as that. Yet this was the beginning, not the end, of the story. The Simplicity Postulate had an impact on the other side of the equal sign: it brought what's now called Bayesian statistics to the fore. If you are one of $N$ people with lottery tickets and the draw is fair, your chance of winning is $1/N$; that's Classical Statistics 100. But Jeffreys was grappling with questions for which no draw can be designed, like the probability that the earth's core is molten. (This was still an open question at that time; Jeffreys himself would soon help to close it). For questions of this sort, scientists make educated guesses. They use what they know about the earth, revising their probability estimate as they learn more. Wrinch and Jeffreys called this inverse probability because it's calculated from the outcome instead of vice versa. Inverse probability seemed fuzzy and subjective to their critics at the time, but Jeffreys would hone it to respectability.

After writing seven papers together, Wrinch and Jeffreys went their separate ways. In addition to developing Bayesian statistics and writing many influential books, among them Scientific Inference, Jeffreys became an eminent geoscientist, a Fellow of the Royal Society, knighted, and the winner of just about every prize except the Nobel. He always acknowledged his debt to Wrinch. "I should like to put on record my appreciation of the substantial contribution she made to this work, which is the basis of all of my later work on scientific inference," Sir Harold wrote after her death [2].

Wrinch was drawn to biology. This wasn't sudden: her friend D'Arcy W. Thompson, author of the magisterial *Growth and Form*, had been nudging her in that direction for several years. Everyone except perhaps biologists agreed that biology was ripe for an overhaul, with theory and experiment, not classification, at its base. The Rockefeller Foundation funded mathematicians and physicists, Wrinch among them, to apply their insights to its fundamental questions. She helped found the Theoretical Biology club, a small, diverse, and influential group that tried to map its logical pyramid. Another founder, in thrall to Russell's logic, planned a *Principia Biologica*. For her part, Wrinch took aim at the chromosome, "looking forward to a future in which the ... chromosome [is] recognized as providing the most delicate and illuminating object for the demonstration of the principles of the mathematical theory of potential and the concepts of pure physical chemistry" [6, p. 551]. But soon she turned from chromosomes to proteins, not as a logician cleaning up a theory-strewn landscape, but as a theorist in the thick of the Stage 3 fray.

Experiments in the nascent science of protein structure suggested that proteins were molecules, not colloids. This meant they had definite shapes. The cage-like model she proposed, the first ever for protein molecules, catalyzed a complicated uproar on both sides of the Atlantic. The bones of contention were not differential equations but the relative values of vision and fact. Her model seemed to explain and predict protein folding, the numbers of amino acids in protein molecules, and the symmetries of protein crystals. It even suggested the possibility of designer drugs. The devil lurked in the details of these explanations and predictions: what mechanisms accounted for folding? There wasn't enough room in the cage for the protein's amino acids! The chemical bonds that snapped her cages shut might not really exist! In hindsight we can see that the probabilities her supporters and detractors assigned to her model varied directly with their affinities for simplicity. The main idea is simple and elegant, her supporters argued; let's develop its implications and address the details later. No! her opponents retorted, sometimes in unprintable language: if the details are wrong, the model is nonsense. Nor was it just about science. Turf wars, anti-feminism, and clashing personalities kept the cauldron boiling for years.

Wrinch lost out in the end, but she never accepted the polypeptide structure for proteins, not even after Nobel prizes were awarded for it. Instead, she refined her model, over and over, to the end of her life. In a curiously parallel postscript, Sir Harold held out against continental drift to the end of his life, though scientists around the world had accepted it.

The Simplicity Postulate is history, but it says something still. Not in the precise, quantitative way its formulators had hoped, but as a lasting insight. We often *do* equate simplicity with probable truth, instinctively. Let's return to the brute facts of birdsong in the spring. Each fact should be written on a separate sheet of paper, Wrinch said. We'll leave her there (as she never took it farther); we can only guess how she would group the sheets, and with what theories she might link them. But we can answer the question, where, on the Wrinch-Jeffreys evolutionary scale, is this science today? I google *why do birds sing in the spring*, get about 154,000,000 results in 1.02 s, and find it's reached stage 4. My question, I learn, was settled in 2008. "Bird brain study sheds light on why they sing in spring," said the Telegraph [1]. British and Japanese scientists had established beyond doubt that "cells on the surface of the brain trigger hormones when the days get longer." British newspapers, and the BBC, trumpeted the story to the world. Yet the reporters are unlikely to have read the scientific papers. So why their enthusiasm? Because an explanation so simple surely must be true.

Postscript: this hormone action can probably be modeled by differential equations.

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