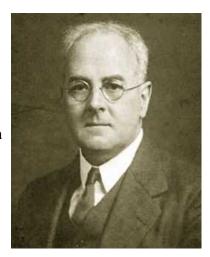Lewis Fry Richardson

In his book *Does God Play Dice?* (1989), Ian Stewart described English physical scientist, applied mathematician, inventor and sociometrist **Lewis Fry Richardson** (October 11, 1881 – September 30, 1953) as "an unorthodox deviser of half-baked ideas whose name floats in and out of the history of applied dynamical systems." Now that's just the kind of person who should make an interesting Person of the Day. He had a penchant for grand ideas, not all of which were feasible. Never in the mainstream of science, Richardson openly admitted his failures. He was a meteorological visionary, who set himself the task of establishing a numerical weather-forecasting model, which likely marked the beginning of the modern science of weather predictions, with Richardson heralded as its grandfather. However, the lack of computers made it impossible to quickly calculate the group of equations that applied to measurements of heat, cloudiness, humidity, etc., which could project how these factors would change over time.

A pacifist, Richardson collected vast amounts of data on what he called "deadly quarrels," which ranged in size from World War I to gang wars in Chicago. He characterized the intensity of the "quarrels" by the logarithm of the number of persons who lost their lives in them and found that intensity was inversely proportional to frequency. Unfortunately his numerical studies didn't suggest ways to prevent the outbreak of deadly quarrels. In his lifetime Richardson was best known for his studies of atmospheric turbulence, performing many terrestrial experiments. This led to his proposal of what is now known as the Richardson number for predicting whether turbulence will increase or decrease. It is a dimensionless number that expresses the ratio of potential to kinetic energy, $Ri = gh/u^2$,

where g is the acceleration due to gravity, h a representative vertical lengthscale, and u a representative speed. Richardson summarized it in his 1920 paper "The Supply of Energy from and to Atmospheric Eddies," with his well-known parody of Jonathan Swift's doggerel about fleas: "Big whorls have little whorls that feed on their velocity, and little whorls have smaller whorls and so on to viscosity." In 1999, meteorologist G.K. Vallis observed: "What is turbulence? Turbulence is like pornography. It is hard to define, but if you see it, you recognize it immediately."

Richardson was born in Newcastle upon Tyne, Northumberland, to a prosperous Quaker family. He entered Bootham School in York in 1894, where he developed a fascination with science, in particular, meteorology. He spent two years at the Durham College of Science, where he studied mathematics, physics, chemistry, botany, and zoology. He completed his education at King's College, Cambridge, where he developed an expertise for numerical solutions of differential equations, graduating with a First Class degree in the Natural Science Tripos in 1903. In the next few years he held a variety of positions. He worked at the National Physical Laboratory (1903-04), taught at University College, Aberystwyth (1905-06), was a chemist with the National Peat Industries (1906-07), headed the physical and chemical lab of the Sunbeam Lamp Company (1909-12), returned to teaching, this time at Manchester College of Technology (1912-13), and worked for the Meteorological Office at Eskdalemuir Observatory (1913-16). Because of his strong commitment to pacifism, during WWI he was a conscientious objector, which subsequently disqualified him from holding most academic posts. He witnessed the horrors of war when at the age of 35 he joined the Friends' Ambulance Unit in the Champagne district of France. His deep convictions led him to study the statistics, dynamics, and reasons for the onset of war. The result was *The Mathematical Psychology of War* (1919).

While Richardson's battlefield experiences had considerable influence on his later investigations into peace research, the immediate result was an investigation of weather forecasting. Early in the 20th

century weather forecasting was based either on an empirical approach of gathering data and drawing inferences from them, or a theoretical approach of explaining atmospheric motions by means of the laws of physics. Around 1903 Norwegian physicist and meteorologist Vilhelm Bjerknes advocated a computational approach of bringing together the full range of observation and the full range of theory to predict the weather. Richardson was the first person to make a full trial of Bjerknes's program. Perhaps to help maintain his sanity in the trench warfare, during the intervals when he was not transporting wounded soldiers back from the front, Richardson made tens of thousands of laborious manual weather computations. He prepared a sample forecast based on his imaginative idea for a method of using mathematics to forecast the weather by solving the equations of atmospheric motion.

Richardson described his method in *Weather Prediction by Numerical Process* (1922). The idea was to lay a grid over the landscape and calculate the behavior of the atmosphere in each cell. He conceived of a "Forecast Factory" in which 64,000 people would gather to do the math, each working in concert, operating desk-calculators to keep ahead of the current weather. The workers would sit in tiers inside a great spherical theater. The director in charge of the project would sit atop a pedestal in the middle, shining a beam of light on those places where the calculation was getting ahead or falling behind. He operates "like the conductor of an orchestra in which instruments are slide-rules and calculating machines." Each "calculator" computes the weather in a given cell based on physical equations, observations streaming in from the field, and the results passed along from neighboring cells.

Richardson had the details wrong but the basic concept was correct. While his fanciful idea for the "Forecast Factory" was impractical, the underlying process he envisioned was prophetic. Today's weather forecasting aided by computers, satellites and a global network of observatories follows a process that is very similar to and clearly influenced by Richardson's fantasy. A theoretical flaw in Richardson's scheme is the grid size; subdividing the surface of the earth into 64,000 cells would make

a typical square cell more than 50 miles on a side, far too large for reliable predictions. Even if we imagine dramatically increasing the number of cells, there is no practical way to collect the required data from the millions of locations over the oceans of the world. Richardson was obviously unaware that the forecasts would require a billion billion calculations. This many would take his 64,000 human computers over 1000 years just to predict the next day's weather. More recent data experiments indicate that the weather is inherently chaotic, in the sense that a given set of initial weather conditions does not always yield the same result. Although modern meteorologists are quite accurate in their short-term predictions, any attempt to predict the weather precisely more than a few days into the future is doomed to failure.

At the end of WWI Richardson went to work for the Meteorological Office at Benson, Oxford, but left in 1920 when it was militarized by integration into the Air Ministry. He burned his papers when the military used his work on turbulence to improve methods to spread poison gas. He subsequently became the head of the physics department at Westminster Training College. At the age of 47 he obtained a doctorate in mathematical psychology from the University of London, the same year he was elected a Fellow of the Royal Society. From 1929 to 1940, he was Principal of Paisley College of Technology in Scotland. In 1940, he retired to do research on war. His results were published posthumously as *Arms and Insecurity; a Mathematical Study of the Causes and Origins of War* and *Statistics on Deadly Quarrels* (1960). Richardson showed how mathematical modeling techniques and statistical analysis could be applied to quantitatively investigate questions relating to war and peace. He organized the data regarding the number of human deaths caused by deliberate action in hopes of testing theories about the causes of war. He used many different variables, but sadly concluded that war is a permanent feature of the human condition and the causes of war seem to be random.

Richardson died at Kilmun, Argyll, Scotland when he was almost 72. He was a dreamer and

civilization cannot progress without dreamers. His sometime absurd sounding ideas for measuring atmospheric conditions and forecasting the weather proved to be right on. What was needed was the time for technology to catch up with the dream. Perhaps his attempt to quantify war will at some future time have beneficial effects, perhaps even contribute to the abolishment of such horrific conflicts. In defining the magnitude of war to be the base-10 logarithm of the number of deaths, a magnitude five war is one that leaves a hundred thousand dead. World Wars One and Two were both over magnitude seven, killing tens of millions each. A conflict of magnitude one would kill only ten or so people. He even included wars of magnitude zero. This would be a conflict in which only one person was killed – something more commonly called a murder.

Quotation of the Day: "Another advantage of a mathematical statement is that it is so definite that it might be definitely wrong; and if it is found to be wrong, there is a plenteous choice of amendments ready in the mathematicians' stock of formulae. Some verbal statements have not this merit; they are so vague that they could hardly be wrong, and are correspondingly useless." – Lewis Fry Richardson