

In today's excerpt - flies, elephants, cities, and ideas:

"Scientists and animal lovers had long observed that as life gets bigger, it slows down. Flies live for hours or days; elephants live for half-centuries. The hearts of birds and small mammals pump blood much faster than those of giraffes and blue whales. But the relationship between size and speed didn't seem to be a linear one. A horse might be five hundred times heavier than a rabbit, yet its pulse certainly wasn't five hundred times slower than the rabbit's. After a formidable series of measurements in his Davis lab, [Swiss scientist Max] Kleiber discovered that this scaling phenomenon stuck to an unvarying mathematical script called 'negative quarter-power scaling.' If you plotted mass versus metabolism on a logarithmic grid, the result was a perfectly straight line that led from rats and pigeons all the way up to bulls and hippopotami. ...

"The more species Kleiber and his peers analyzed, the clearer the equation became: metabolism scales to mass to the negative quarter power. The math is simple enough: you take the square root of 1,000, which is (approximately) 31, and then take the square root of 31, which is (again, approximately) 5.5. This means that a cow, which is roughly a thousand times heavier than a woodchuck, will, on average, live 5.5 times longer, and have a heart rate that is 5.5 times slower than the woodchuck's. As the science writer George Johnson once observed, one lovely consequence of Kleiber's law is that the number of heartbeats per lifetime tends to be stable from species to species. Bigger animals just take longer to use up their quota. ...

"Several years ago, the theoretical physicist Geoffrey West decided to investigate whether Kleiber's law applied to one of life's largest creations: the superorganisms of human-built cities. Did the 'metabolism' of urban life slow down as cities grew in size? Was there an underlying pattern to the growth and pace of life of metropolitan systems? Working out of the legendary Santa Fe Institute, where he served as president until 2009, West assembled an international team of researchers and advisers to collect data on dozens of cities around the world, measuring everything from crime to household electrical consumption, from new patents to gasoline sales.

"When they finally crunched the numbers, West and his team were delighted to discover that Kleiber's negative quarter-power scaling governed the energy and transportation growth of city living. The number of gasoline stations, gasoline sales, road surface area, the length of electrical cables: all these factors follow the exact same power law that governs the speed with which energy is expended in biological organisms. If an elephant was just a scaled-up mouse, then, from an energy perspective, a city was just a scaled-up elephant.

"But the most fascinating discovery in West's research came from the data that *didn't* turn out to obey Kleiber's law. West and his team discovered another power law lurking in their immense database of urban statistics. Every datapoint that involved creativity and innovation - patents, R&D budgets, 'supercreative' professions, inventors - also followed a quarter-power law, in a

way that was every bit as predictable as Kleiber's law. But there was one fundamental difference: the quarter-power law governing innovation was *positive*, not negative. A city that was ten times larger than its neighbor wasn't ten times more innovative; it was *seventeen* times more innovative. A metropolis fifty times bigger than a town was 130 times more innovative.

"Kleiber's law proved that as life gets bigger, it slows down. But West's model demonstrated one crucial way in which human-built **cities** broke from the patterns of biological life: as **cities** get bigger, they generate ideas at a faster clip. This is what we call 'superlinear scaling': if creativity scaled with size in a straight, linear fashion, you would of course find more patents and inventions in a larger city, but the number of patents and inventions per capita would be stable. West's power laws suggested something far more provocative: that despite all the noise and crowding and distraction, the average resident of a metropolis with a population of five million people was almost *three times* more creative than the average resident of a town of a hundred thousand."

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Title: *Where Good Ideas Come From*

Publisher: Riverhead

Date: Copyright 2010 by Steven Johnson

Pages: 8-11

Tags: Animals, Innovation, Science, **Cities**