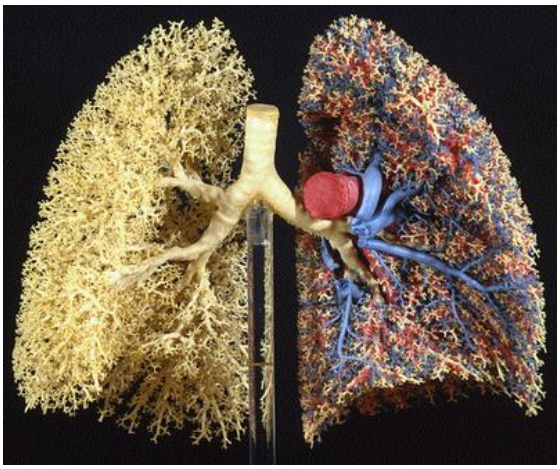
Fractals and Human Biology

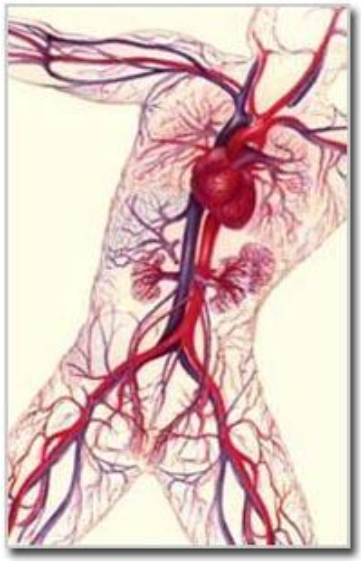


We are fractal. Our lungs, our circulatory system, our brains are like trees. They are fractal structures.

Fractal geometry allows bounded curves of infinite length, and closed surfaces with infinite area. It even allows curves with positive volume, and arbitrarily large groups of shapes with exactly the same boundary. This is exactly how our lungs manage to maximize their surface area.

Most natural objects - and that includes us human beings - are composed of many different types of fractals woven into each other, each with parts which have different fractal dimensions. For example, the bronchial tubes in the human lung have one fractal dimension for the first seven generations of branching, and a different fractal dimension from there on in.

Our lungs cram the area of a tennis court into the area of just a few tennis balls.



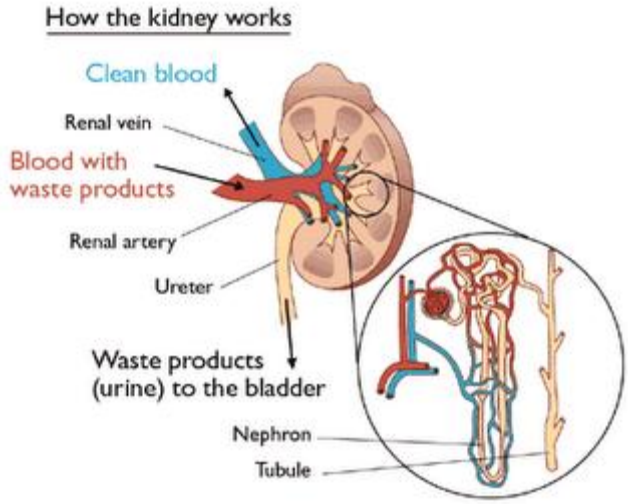
The Three-Quarter Power Law

Fractal geometry has revealed some remarkable insights into a ubiquitous and mysterious "three-quarter" law. This particular power law models the way one structure relates to and interacts with another. It is based on the cube of the fourth root. Many three-quarter laws have emerged from the measurement of seemingly unrelated systems, modeling the way that one structure varies with another.

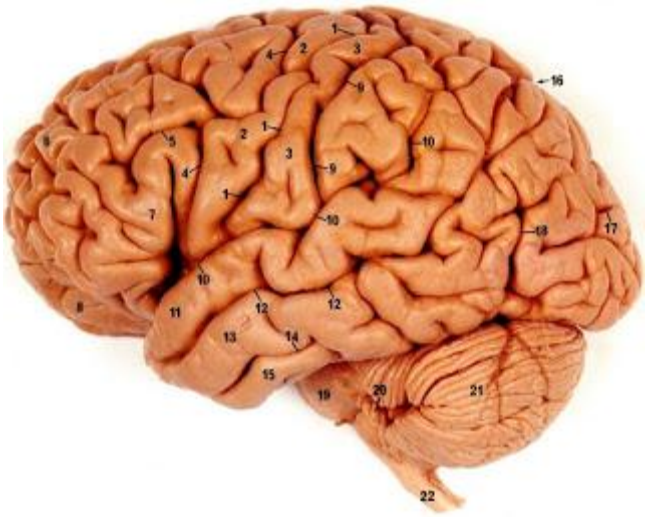
For a long time now, physiologists have had an empirical understanding of how much blood flows through our circulatory system, and how this relates to the physical size of the vessels that carry it. Research employing fractal rules has revealed a three-quarter power rule law even in the circulatory system.

Our arteries, which account for just 3 per cent of our bodies by volume, can reach every cell in our bodies with nutrients. In the kidneys and lungs, our arteries, veins, and bronchioles all manage to intertwine around a common boundary.

The arteries that deliver the blood, and the veins that take it away, need to share a common interface with the surface of the lungs, in order to aerate the blood. The arteries must provide every cell in our body with nutrients, using the minimum amount of blood.



The kidneys, the liver, the pancreas are all organs constructed along self-similar fractal rules. So too is the most remarkable of all those we know on the planet - the human brain.



The Mysterious Brain

One thing we can say with certainty about the brain is that it is a very fractal piece of kit ! It has an obvious fractal structure. You have only to look at it to see that. It is very crinkled and wrinkled and highly convoluted, as it folds back and back on itself.

"There is a natural evolutionary route from universal mathematical patterns to the laws of physics to organs as complex as the brain." ... Ian, the English Fractal Guy

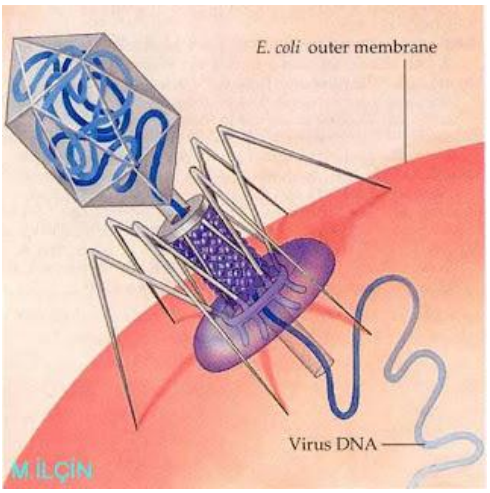
It is deeply ironic that this remarkable organ, which is the seat of the mind, and which either created or discovered (we don't know which) the mathematical rules on which it and the entire universe turns, cannot explain or understand its own functioning.

Understanding how our brains function is probably the greatest challenge facing the scientific community at this time. Fractal geometry is at the leading edge of research in this area.

Fractals and Medical Research

All aspects of nature follow mathematical rules and involve some roughness and a lot of irregularity. For example, complex protein surfaces fold up and wrinkle around towards three-dimensional space in a dimension that is around 2.4. Antibodies bind to a virus through their compatibility with the specific fractal dimension of the surface of the cell with which they intend to react.

Consequently, many of the current developments and findings in fractal geometry are in work with surfaces.



Viruses and Bacteria

The receptor molecules on the surfaces of all viruses and bacteria are fractal. Their positioning techniques, the methods they use to determine the chemistry of the body they have invaded and how they will interfere with that body's chemistry, and their binding functions, emerge mathematically by way of the deterministic rules of fractal geometry.

AIDS

The dynamics of the AIDS virus in the human body has been modeled with fractal geometry, which provides the answer to the long-standing puzzle surrounding the unusually long incubation period of the AIDS virus. Many patients remain HIV positive for as long as ten years before the virus decides to kick in, and the onset of the full-blown disease reveals itself in the body.

As the immune system begins to fall apart, the AIDS virus starts to behave chaotically. Studies of the virus at this stage have revealed significant changes in the fractal structure.

Fractal geometry unravels the structural differences that occur at the end of the incubation period of the virus.

Detecting Cancer

The surface structures of cancer cells are crinkly and wrinkly. These convoluted structures display fractal properties which vary markedly during the different stages of the cancer cell's growth.

Fractal geometry I being employed in the initial detection of the presence of cancer cells in the body.

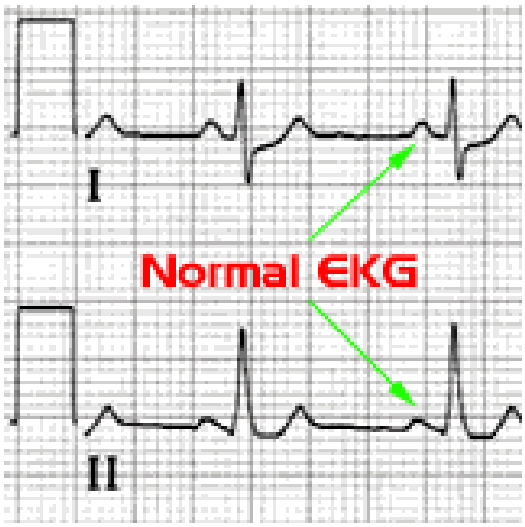
Using computers, mathematical pictures can be obtained, which reveal whether or not cells are going cancerous. The computer is able to measure the fractal structure of cells. If cells are too fractal, it spells trouble. There is something wrong with those cells.

Women at Risk

The fractal dimension of cancerous material is higher than that of healthy cells. Alan Penn, who is Adjunct Professor of Mathematic and Engineering at George Washington University, describes his work in this area, "MRI Breast Imaging may improve diagnosis for the 4,000,000 woman at risk for whom mammography isn't effective. Clinical application of MRI has been hampered by difficulty in determining which masses are benign and which are malignant. Research has focused on developing robust fractal dimension estimates which will improve discrimination between benign and malignant breast masses."

Bubbly Bones and Breaks

Bones contain air bubbles. Bone fractures are fractal. Fractal geometry is being applied particularly and most effectively in the healing of brittle bone fractures.



Fractal Beats

The body structures of all of nature's animals are fractal, and so too is their behavior and even their timing.

Our heartbeats seem regular and rhythmical, but when the structure of the timing is examined in fine detail, it is revealed to be very slightly fractal. And this is very important.

Our heartbeats are not regular. There is an important tiny variation.

This fine variation reduces the wear and tear on the heart drastically. Additionally, heart disease can be detected by extreme and arrhythmic fractal behavior.

"If the beats were regular, the stresses on the heart would be the same on every beat."
... Benoit Mandelbrot