FRACTAL EVOLUTION

Evolution by BITs and Pieces: An Introduction to Fractal Evolution

The membrane boundary enveloping each biological cell comprises the structural basis of a biological processor system (see article: Cellular Consciousness). As a processor, the cells membrane receptors scan the environment for signals. Obviously the environment is awash in signals. If all the signals were audible, the environment would sound like blaring noise. However, the specificity of reception that is characteristic for each receptor IMP, enables it to distinguish its complementary signal out of all the jumbled ambient noise. The cells ability to selectively filter useful information out of "chaotic" noise resembles the function of Fourier transformations [mathematical filtering processes which find signals within what appears to be noise] on complex inputs to perceive specific frequencies as informational signals. While the environment is in a sense "chaotic," with hundreds and thousands of simultaneously-expressed "signals," the cell can selectively read only those signals that are relevant to its existence.

Based upon the functional and structural features of the cell membrane, each single cell (e.g., amoeba) represents a *self-powered microcomputer system*. As in digital computers, the power or information handling capacity of the "cellular" computer is determined by the number of its BITs it can manage. In computers, the BITs are gate/channel complexes, in the membrane processor, the BITs are represented by receptor/effector complexes. The IMP molecules comprising the cells BITs have defined physical parameters and therefore can be "measured."

The dimension of the IMP proteins is approximately the same as the thickness of the membrane. Since the IMPs, by definition, reside within the membranes bilayer, the proteins can only be arranged as a monolayer (meaning the IMPs can not be stacked upon one another). To use the bread and butter and olive sandwich metaphor, there are only so many olives that can be layered on the bread. To have more olives in the sandwich requires the use of a larger slice of bread. The same applies to increasing the number of perception-IMP units in the membrane: the more IMPs-the more surface area of membrane required to hold them. The cells information processing capability (reflected in the number of perception proteins) is directly linked to the surface area of the membrane.

The profound point of this discourse...Biological awareness is a measurable property, and is *directly correlated* with the surface area of the cells membrane. Consequently the computing power of a cell is physically determined by limitations imposed on cellular dimensions.

The ***first phase of evolution*** of life concerned the development and refinement of the individual biological computer 'chip', the primitive bacterium. The size of these primitive organisms is constrained by the fact that they posses a rigid outer skeleton, derived from the polysaccharides of the glycocalyx. The matrix produced by the cross-linking of the sugar molecules in this "coat" provides for the cells protective "skeleton," called a capsule. The capsule physically supports and protects the cells thin membrane from rupturing under the strains of osmotic pressure.

Osmotic pressure is the force generated by the desire of water to move through a membrane to "balance" the concentration of particles on each side of the membrane barrier. The cells cytoplasm is packed with particles compared to the water in which cells live. Water from the external environment will pass through the membrane to dilute the concentration of cytoplasmic particulates. The cell would swell up with water and the pressure would cause the delicate membrane bilayer to rupture, killing the cell. The glycocalyx exoskeleton resists life threatening osmotic pressure.

Bacteria are the cellular equivalent of invertebrates, (animals not possessing an internal supportive skeleton (e.g., clams, insects, jelly fish). While the skeleton protects the bacterium, its rigid nature also limits it. The bacterial cell size is limited by its outer capsule. The size limitation restricts the amount of membrane the cell can possess. Membrane surface area is proportional to awareness, based upon the number of IMPs it can contain. The bacterial capsule limits the cells evolution since there is a cap on the number of units of perception the membrane can contain.

In fact, most of the bacteriums membrane surface area is used to house the necessary IMP complexes required for cell survival. However, each bacterium is also capable of *learning* about six additional environmental "signals." For example, a bacterium may acquire the ability to resist an antibiotic introduced into the environment. It does this by creating a surface receptor that binds and inhibits the molecules of the antibiotic. The new receptor is fundamentally the equivalent of a protein "antibody" that our immune cells create to neutralize an invasive antigen.

The creation of a new receptor, by definition, implies that there must be a new gene created to remember the amino acid code for that protein. In bacteria, these "new" *memory* genes are present as tiny circles of DNA called plasmids. The plasmids are not physically attached to cells heredity-providing chromosome and float freely in the cytoplasm. Bacteria are capable of creating an average of about six *different* plasmids, each derived from a unique learning "experience." The limitation on the number of plasmids the cell possesses is not due to an inability to make DNA. For the bacterium can make thousands of copies of any of the individual plasmids it possesses. The limitations must be related to the fact that each "new" protein perception complex requires a unit of surface area to express its functions. The inability to expand its membrane (i.e., surface area) limits the bacteriums ability to acquire new perceptions (awareness).

The more awareness the greater the ability to survive. Limitations upon individuals increasing their awareness, led to bacteria living in loosely knit communities. If an individual bacterium can "learn" six facts about the environment, than a hundred bacteria are collectively capable of being aware of 600 facts. Bacteria developed mechanisms to transfer copies of their plasmids to other bacteria in the community. By transferring copies of their "learned" DNA, they share their "awareness" with the community. Bacteria can transfer a plasmid to another individual. The recipient bacterium can use the donated plasmids "awareness" during its life, but generally can not pass copies of the plasmid on to its daughter cell progeny.

Bacteria possess fine tentacle-like projections that extend from their outer surface called pili. When the pili from two bacteria touch, the pilus membranes can momentarily fuse, joining the cytoplasm of the two cells together. At the moment of fusion, the two bacteria can exchange copies of their plasmids. Bacteria are also able to scarf-up free floating DNA in the environment, so plasmids released into the environment, as might occur when a cell dies and its cytoplasm leaks out, may be scavenged by other cells. However, the environment is tough on free-floating DNA and the plasmids easily break down. A third, more effective means of distributing "awareness" plasmids arose when bacteria learned how to package their plasmid DNA into protective protein shells, creating viruses. Viruses contain "information" that are released to other individual cells in the environment. Some viruses kill the cells that pick them up, while other viruses protect the cells that they "infect." Sometimes "information" is life affirming, sometimes it's lethal.

Bacterial communities evolved a means to increase their survival by deploying an polysaccharide extracellular matrix to envelope all of the cells in the community and "protect" them from the ravages of the wild environment. Individual bacteria were able to move through "irrigated" channels within the matrix. The channels also allowed a communication of extracellular materials and information molecules, which provided a communal integration among all of the members of the community. The cellular community may be populated with a variety of bacterial species. For example, oxygen-fearing anaerobic forms of bacteria can live at the bottom of a community, while oxygen-loving aerobic bacteria are present in upper levels of the same community. Bacteria within the community are readily able to exchange their DNA, and in so doing enable the cellular citizens to acquire specialized, differentiated functions.

These matrix-encased bacterial communities are called biofilms (see illustration below). Biofilms have become very important since they are now recognized to protect bacterial communities from antibiotics. The bacteria that form tooth cavities are actually biofilm communities, which resist our efforts to scour them from our teeth. The resistive and protective nature of the biofilms enabled these communities to be the first life forms to leave the ocean and live on the land.

Many years ago, biologist Lynn Margulis founded the concept that mitochondria were bacterial-like organisms that invaded the cytoplasm of more advanced nucleus-containing cells called eukaryotes. At first her ideas were ridiculed by the establishment, but over the years it has become a widely accepted belief. Interestingly, an understanding of the communal nature of bacteria in biofilms offers another interpretation.

The micrograph on the left illustrates a an example of a biofilm in a human lung. The infective pseudomonas bacterial clump is encased in a dark staining extracellular matrix (see arrow) comprising a biofilm. Encapsulation within the matrix protects the bacteria from the immune systems efforts to destroy them. The matrix, primarily made of carbohydrates, can also contain the muscle proteins, actin and myosin, which are found bound to the outer surfaces of some bacteria. The external actin and myosin proteins enable the bacteria to move within the films matrix.

The micrograph on the right is the same picture, but with a "membrane " drawn around the films periphery. A membrane around the film would enable the bacterial community to finely control the composition and character of their environment, a necessary development that would enhance their survival. This modified film resembles the cytological anatomy of the evolutionarily more advanced eukaryotic cell. In this case the bacteria would represent the cells organelles and the films matrix would represent the cytoskeletal-rich cytoplasm between the organelles. Interestingly, the eukaryotes cytoplasm possesses many of the same structural components that characterize the biofilms matrix. This especially true of the actin and myosin which enable the bacteria to move in the film in the same manner that organelles move in the cytoplasm.

The point of this discussion is that the more advanced eukaryotic cell, rather than being an evolved single entity, might represent the evolution of a bacterial community. A cell would represent a finely tuned community of prokaryotes that have differentiated into organelles. Such a hypothesis supports the beliefs of pleomorphic biologists, a small but staunch group of scientists that believe disease related micro-organisms may represent life forms that arose, budded-off, from dying cells. Makes sense.

Regardless, the second phase of evolution saw the origin of the more sophisticated eukaryotic (nucleated) cell. However, evolution ceased when the nucleated cell reached its maximum specific size, for there are physical limitations imposed on cellular life. If the cell attempts to expand its surface area beyond a given size, the cell will become unstable, for if it exceeds certain dimensions, the membrane will not be physically able to constrain the mass of its cytoplasm. This will lead to a rupture of the membrane and a loss of the membrane potential (from which the cell draws its life-giving energy). Also, if the cell exceeds a certain diameter, than the process of diffusion would not enable enough oxygen for metabolic processing to reach the central portion of the cell.

As a result, in the history of evolution, the first 3 billion years were primarily associated with appearance and evolution unicellular organisms (bacteria, algae, protozoans). It was the origin of multicellular organisms that represented an alternative way to expand the membrane surface area (i.e., awareness potential) beyond the limitations of the single cell. Consequently, in what amounted to a third phase of evolution, an increase in biological "computer" power (awareness) resulted from a the same process of organizing into higher order communities. Rather than increasing awareness of the individual eukaryotic cell, the third phase of evolution was concerned with the ordering of individual eukaryotic cell 'chips' into interactive assemblies.

This "phasing" of evolution resembles that which occurred in the computer industry. Texas Instruments developed the chip. Individual chips are the heart of the simple calculator. However, when many chips were integrated and wired together they provided for the computer. When individual computers reached their maximum power, supercomputers were created by assembling many computers into an organized parallel-processing "community." The bacteriums relation to the eukaryotic cell is tantamount to the chips relationship with the computer. The eukaryotic cells relation to the multicellular organism is the same as an individual computers relation to the whole in a parallel-processing network.

In computers, the "power" of the machine is measured in BIT handling capacities. In biological organisms, the "awareness" potential is reflected in the number and variety of integrated IMP complexes. Since the quantity of IMPs is directly linked to "surface area," awareness becomes a factor of shared membrane surfaces in the multicellular organisms.

Consider that surface area relationship in regard to vertebrate brain evolution. First vertebrate brains are small, smooth spheres. As one ascends the evolutionary ladder, the brains become larger and more surface area is subsequently derived from infoldings of the brains surface that produce the characteristic sulci (grooves) and gyri (folds) of more advanced brains. Interestingly, when considering awareness in terms of brain surface, humans are in second place since porpoise and dolphin brains have a larger surface area.

It is proposed that similar to unicellular protozoans, human beings represent another evolutionary endpoint, the highest level of development for a multicellular biological structure. In a series of events redundant to those that occurred in the previous two cycles of evolution, human evolution continued through a process of assembly and integration of individuals into a multi-"cellular" community. In this community known as humanity, each person's role is analogous to that of a single cell in the human construct. In the global view of the Earth as a living organism (Gaia), humans are the IMP equivalents in the Earth's surface membrane. Humans, as receptors and effectors, assemble and integrate into patterned networks (community) in the Earth's envelope wherein they receive environmental "signals" and serve as switching mechanisms of the planet's membrane gates.

These studies reveal that past and future evolution can be mathematically modeled in the structure and elaboration of the cell membrane. The best way to organize two-dimensional membrane surface area into a three-dimensional cell space is to employ fractal geometry.

In Nature, most inorganic and organic structures express an "irregular" pattern. However, within the apparent chaos of the irregularities, one finds that the irregular structures are "regularly" repeated (i.e., they show a form of order). For example, the pattern of branching in a trees twig is often the same pattern of branching that is observed on the trees trunk. The pattern of branching of a major river is identical to the pattern of branching observed along its smaller tributaries. The pattern of branches along the bronchus is a reiteration of the pattern of airway branches along the smallest bronchioles. Similar images of reiterated branching patterns in the body are revealed in the arterial and venous blood vessels and peripheral nervous system.

The French mathematician, Benoit Mandelbrot was the first to recognize that the geometry of many of Natures objects revealed a similar pattern regardless of the scale it was examined on. The more you magnify the image, the more the structure appears the same. Mandelbrot introduced the term "self-similar" to describe such objects. "In 1975, Mandelbrot coined the word fractal as a convenient label for irregular and fragmented self-similar shapes.

The mathematics of fractals is amazingly simple in that it consists of repeating "operations" of additions and multiplications. In the process, the result of one operation is used as the input for the subsequent operation; the result of that operation is then used as the input for the next operation, and so on. Mathematically, all the "operations" use the exact same formula, however, they must be repeated millions of times to get the solution. The manual labor and time required to complete a fractal equation prevented mathematicians from recognizing the "power" of Fractal Geometry until the advent of powerful computers enabled Benoit Mandelbrot to define this new math.

In classical geometry the points, lines, surface areas and cubic structures all represent dimensions expressed in whole integers, 0-, 1-, 2-, and 3-dimensions, respectively. Fractal geometry is employed to model images that are more "interdimensional." For example a curved line is a 1-dimensional object. In fractals the curve can zig-zag so much that it actually comes close to filling the plane. If the curve of the line is relatively simple it is close to a dimension of 1. If the lines curves are so tightly packed that they fill the space, the line approaches 2-dimensions. Fractal Geometry fills in the spaces between whole number dimensions.

A structural characteristic of fractals is relatively simple to understand: fractals exhibit a reiterated pattern of "structures" nested within one another. Each smaller structure is a miniature, but not necessarily an exact version of the larger form. Fractal mathematics emphasizes the relation between the patterns seen in the whole and the patterns seen in parts of that whole. For example, the pattern of twigs on a branch resembles the pattern of limbs branching off of the trunk. Fractal objects can be represented by a "box" within a "box," within a "box," within a "box," etc. If one knows the parameters of the first "box," then one is automatically provided with the basic pattern that characterizes all of the other (larger or smaller) "boxes."

As described in the Mathematics of Human Life article by W. Allman (cited in reference section), "Mathematical studies of fractals reveal that the branching-within-branching structure of a fractal represents the best way to get the most surface area within a three-dimensional space...." While the cell membrane is in reality a 3-dimensional object, its molecular bilayer possesses a constant and uniform thickness. As such the thickness of the membrane can be ignored and the membrane can be modeled as a 2-dimensional "surface-area" structure. Since evolution is the modeling of the membranes awareness (related to its surface area), the efficiency of modeling provided by fractal geometry would most likely reflect that chosen by Nature.

The point is not to get caught-up in the mathematics of the modeling. The point is that the fractal model predicts that evolution will be based upon a reiterated pattern of "structures nested within one another! More specifically, as it relates to a concept of Fractal Evolution, "the pattern of the whole is seen in the parts of the whole," this means that the pattern of the human is seen in the parts (cells) of the human. If one is aware of the pattern by which a cell is functionally organized, than one is also provided insight into the organization of a human. Consider this: the fractal images of smaller structures are miniatures of the larger whole. Therefore, while the structure of humans is a self-similar image of their own cells, the structure of human civilization would represent a self-similar structure of its component humans!

Humans are a fractal image of society, cells are a fractal image of the human. In fact, cells are a fractal image of society as well. The fractal nature of evolution is further implied by the reiterated, self-same patterns observed in each of the three cycles of evolution.