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Cell Walls – the Limits to Growth

In a public lecture at the Royal Society in London on 23 April 2013, Professors Lawrence of Cambridge and Morata of Centro de Biologia Molecular posed the question: How do cells know when to stop proliferating? The argument which was made may be paraphrased as follows. Species evolve and become extinct through natural selection by the physical environment, and research reveals that each species has its own specific DNA. But what is the link between the two i.e. between the DNA of an individual and its shape and proportions, which are what count in natural selection? This is especially problematic when apparently small changes of DNA lead eventually to the major changes of structure which evolution has produced.

This paper explores the question from a perspective which is different from conventional biology and molecular biology. It examines what might be happening at the level of the cell as a unit, what in other contexts might be called ‘particle kinetics’. This approach may suggest new observations and measurements which could be made. The importance of the question cannot be overstated, because it is at the heart of the processes of growth and evolution.

My previous papers describe a new paradigm of evolution, one based on diffusion of genetic changes from an individual which go on to permeate through its whole species. This is different from Darwin’s theory of natural selection which explained evolution as the dynamics of species *per se*. Those species that did not adapt to changing environments became extinct, which left space for the better adapted species to expand into. The unspoken hypothesis was that all the ultimate variations were in some way inherent in populations for natural selection to sift. However, he did say that in the course of very long periods of time there might occur a few individuals in the population who developed special characteristics, which presumably would be the first step towards a new species. Alfred Russel Wallace may have been closer to the mark when he observed a gradation of physical characteristics of land animals on islands on one side of a deep sea trench and a different gradation on the other. The trench was a barrier to diffusion.

Later discoveries showed that a species was characterised by its unique DNA, which was in effect a chemical compound in the form of a very long polymer chain composed of two linked helices of the same length to enable replication, packed into each cell of an individual. Differentiation within a particular DNA molecule can occur both in the length of chains and in the links. This must take place during procreation either by faulty cloning or by some exogenous influence, such as radiation. To become part of the evolutionary process, the modified chain must be passed on in its turn through sperm or egg to the immediate next generation, and then diffuse further by procreation through further generations of the whole species in the course of time.

This approach reduces the analysis to what might be called the kinetics of ‘particles’.

Mutations occur at random in different individuals in different places at different times, but almost all die with the individual because they occur too late to be involved in the procreation process, or because the physical safeguards of the body abort them. Thus it is extremely rare that a mutation passes the individual tests and becomes embodied in the species. Those few which are successful diffuse towards each other through whole populations generation by generation, and may eventually overlap, so that some contemporary individuals have more than one mutation. The process is so slow that it is never likely to go to completion and produce uniformity. The corollary is that individuals in the same species are likely to have different collections of mutations.

What is missing in all this is the link between DNA and physical structure. Differentiation between species occurs both in DNA and in the physical characteristics which respond to the environment, but structure is the characteristic which allows natural selection to operate. The analysis shows that DNA may vary from individual to individual, but not sufficiently to differentiate them into in separate species. However, natural selection does not test for DNA; it operates on physical characteristics alone. It is a process that sifts individuals by their ability to survive in the physical environment which is changing around them. So what is the connection between the shapeless chemical molecule which is cell DNA and the structured entity of the individual?

Materials structures depend ultimately on tensile strength, which is resistance to deformation, and on elasticity, which is the property of recovering shape after deformation. The only part of the whole system which has these properties is the cell wall. Resilience implies cross-linking of macromolecules in the cell wall. If this conclusion is valid, it is possible to speculate as follows:

Structure is certainly related to DNA which determines the general form of the species. The structure of an individual must therefore be the result of an interaction of its DNA with its cell walls. Cell walls must also be characteristic of organs, heart, liver etc, but they require additional input to differentiate them from each other in the same individual, and allow damaged cells to be replaced. It is cell walls that form three-dimensional structures. They must be asymmetric, because symmetry would produce diamond-like regularity. Each wall of a cell could differ in area and in ‘inside’ and ‘outside’ properties. Back to back cell generation i.e. building a new cell on the wall of another would generate mirror images, but cells separated from the matrix would not necessarily show this because they are free to rotate e.g. under the microscope or in a body.

Cell walls contain information and memory, because they have been observed to regenerate *in situ*. The information and memory must be imprinted on cell walls at the earliest stages of the embryo, and passed on to later cells generated in the growth process. This is the information which determines shape and proportions, the limits to growth, and it may develop from the egg membrane which is the only ‘structural’ feature at conception. The special properties of stem cells may be that they have walls which are not yet interactive. If this is so, there must be a process of growing the cell wall for division, which also has a bearing on its properties. The cell wall is not simply a semi-permeable membrane or a protective covering, though it may of course perform both functions. If these components also change with the quality and age of the sperm and the egg, it is possible that they may play a part in determining the eventual physical structure of the organism.

In this model, cell walls must be very complex internally if they are to possess both stereochemical and physical attributes. It seems likely that they may be constructed of helices to account for their material properties of extension and retraction; linear molecular strain would not be enough. But they must also have the stereochemical specificity to allow interaction with their individual's DNA. If cell walls contain genetic information, they may also gather mutations like the DNA within the cell, both those present at the embryonic stage and those produced later. This would probably affect all cells generated from them as a template.

The alternative to having information contained within cell walls would be that it is relayed by some mobile entity e.g. in bloodstream. Even then, there would have to be detectors at the cell to receive the required information and communication to the central memory of the system, wherever this was located.

A coherent living entity must have some overall connection which links all structural parts together i.e. the parts must be linked to the whole to function as a system. The obvious conduit for this is the network of all cell walls. The conclusion is that cell walls must therefore have the physical and stereochemical structures to link all cells in that individual. A living entity then grows to the size which the network of cells, or skin, can accommodate. Similar effects would then occur at the level of the subsystems or organs within the entity, but with specific additional information. Somewhere in this system there must be a clock by which the processes are synchronised. This would presumably have to be based on the rates of chemical processes within cells, because there is nothing else, unless of course there are also chemical processes going on in cell walls too. Cell walls seem to become less resilient with the age of the individual, which may give a clue. This might also involve oxidation, which is known to reduce the resilience of synthetic polymers by causing the cross-linking of the macromolecules by free radical processes.

There are enough degrees of freedom in this system to allow the differentiation between individuals on which natural selection operates. The criteria of selection vary with the local environment i.e. from time to time and place to place. But natural selection is not trying to 'improve' living entities. What is optimum at one time in any place may not be optimum at a different time, and *vice versa*. Defunct species might have done very well in environments which occurred after they became extinct. It is a matter of chance.

This sort of analysis which ranges from biology and molecular biology to particle kinetics and material science provides a mechanism by which evolution occurs. A new species is formed when a line of progeny emerges of individuals with enough coherent new structural features for natural selection to differentiate them as a group from the 'home' species. With the passage of time, individuals in the new 'species' begin to diverge from each other in their turn.

This is all very speculative, of course, but the problem of linking physical structure with the biochemistry of species requires some sort of bridge. Much of what I have proposed could be confirmed by microscopy and modern analytical techniques (plus perhaps a modicum of materials testing!). It suggests plenty of avenues to explore in what is an extremely important subject. Different types of living entity might have their own variations on the basic concept of 'particle kinetics'.

Species are not homogeneous through time. In fact I have called them ‘semi-homogeneous’ through time in my book on systems *A Degree of Freedom*. By this I mean homogeneous for long enough to enable us to recognise them as such i.e. metastable states. These are the periods during which enough transmitted mutations accumulate to differentiate species. Since each successful mutation would be very rare, the length of time taken to achieve a sufficient number for differentiation into new species would be very long compared to the lifetime of an individual. However, populations are ever changing because of the accumulation of mutations in what appears to be a stable condition. In the course of time some species come to prominence and others fade into obscurity by the physical tests of natural selection, now recognised only by what remains of their structures. So, archaeology too!

That’s the kinetics of evolution. That’s life!

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26 May 2013