While van Flandern, as stated earlier, was very up front about rejecting miracles, others didn't necessarily agree. As one told me, that supposes he knows all that can be known about the universe. It is a pity that this talented group is so against the notion of a Creator, who told us that He did create the universe in a specific way some six thousand years ago as measured by Earth clocks. It is only left up to us to find out some of the details.

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Evolution of multicellularity: what is required?

Shaun Doyle

All evolution assumes either the augmentation of some prior system to fit a new need, or lateral gene transfer adding information for the same end. Even systems that seem to require completely new structures (feathers for example) are assumed to be modified from pre-existing structures. However, there are two significant events in evolutionary history where far more would have been required—the origin of life, and the origin of co-ordinated multicellularity.

Requirements for multicellular evolution

Genetic sameness

The first requirement for multicellularity to emerge is that all the cells must contain the same genetic information. Wolpert and Szathmáry provide a good overview of why genetic sameness is required for a multicellular organism to be viable as an individual:

> 'The first step in the development of a complex organism is the establishment of a pattern of cells with different states that can differentiate along different pathways. … [P]atterning processes require signalling between and within cells, leading ultimately to gene activation or inactivation. Such a process can lead to reliable patterns of cell activities *only if all the cells have the same set of genes and obey the same rules* [emphasis added].'[1]

Without the same genetic blueprint to work from, there is no guarantee that cells will be able to communicate properly so as to co-ordinate their actions.

A new level of biological organisation

Evolution requires more than a mere augmentation of an existing system for co-ordinated multicellularity to evolve; it requires the *ex nihilo* creation of an entirely new system of organisation to co-ordinate cells appropriately to form a multicellular individual. Nedelcu and Michod concur:

> 'The current hierarchical organization of life reflects a series of transitions in the units of evolution, such as from genes to chromosomes, from prokaryotic to eukaryotic cells, from unicellular to multicellular individuals, and from multicellular organisms to societies. During these evolutionary transitions, *new levels of biological organization are created* [emphasis added]'.[2]

Williams talks of the irreducible structure of the cell, and finds a universal example in *autopoiesis* (self-making).[3] He describes five levels of organisation in all living things that are needed for autopoiesis to occur:

1. Perfectly-pure, single-molecule-specific biochemistry
2. Molecules with highly specific structures
3. Highly structured molecules that are functionally integrated
4. Comprehensively regulated information-driven metabolic processes
5. Inversely-causal meta-informational (information about information) strategies for individual and species survival.

Moreover, each level is greater than the sum of the levels that make it up such that the only way these levels can be explained is by *information*.

> 'Each level is built upon, but cannot be explained in terms of, the level below it. And between the base level (perfectly pure composition) and the natural environment, there is an unbridgeable abyss .'[4]

To Williams' autopoietic hierarchy, I wish to add another level of structure found only in multicellular organisms: *intercellular co-ordination*. The organism has strategies for arranging and differentiating its cells for survival and reproduction. With this comes a communication network between the cells that regulates the positioning and abundance of each cell type for the benefit of the whole organism. A fundamental part of this

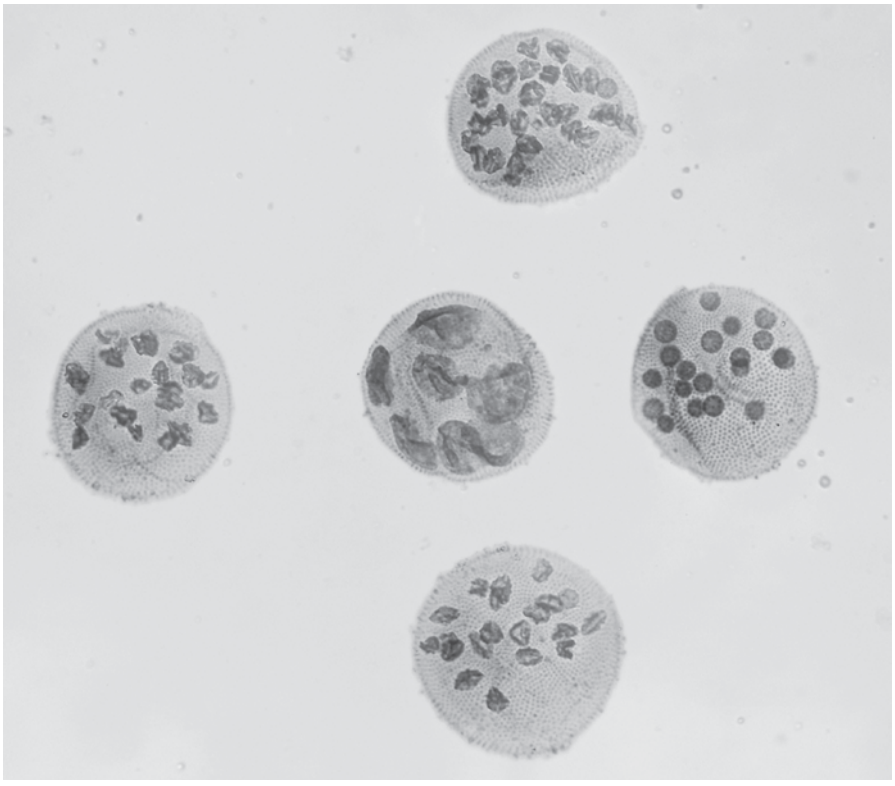

Photo by Karl Dolenc <www.istockphoto.com>

Volvox spp. fail to meet the requirements to achieve true multicellularity.

organisation is cellular differentiation, which is ubiquitous in multicellular organisms. This level cannot be explained by the sum of the parts, cells, and requires co-ordination from an organisational level above what exists in individual cells.

Biologist Eric Davidson[5] identifies a 4-level hierarchy of control in multicellular organisms that constitutes a gene regulatory network. This gene regulatory network is essential for the development of the single cell zygote into a full-fledged multicellular individual. To put it in an approximate Linnaean framework, the hierarchy consists of *kernels*[6] that roughly determine phylum body plan, *plug-ins*[7] and *input/output linkages*[8] that approximately determine class, order and family body structure, and *differentiation gene batteries*[9] that carry out the terminal stages of development and contribute to variation at the genus and species level.

Repair and maintenance strategies

Repair and maintenance strategies are integral for the survival of the adult multicellular individual because cellular selection operates with cell populations, including multicellular organisms, to select for the most reproductively aggressive cells. This needs to be controlled at the organismal level to maintain bodily integrity. To do this, most systems in multicellular animals undergo a process of serial differentiation.[10] In this system, multipotent[11] stem cells are essential, though maintained at low population levels.

Cellular selection vs organismal integrity[12]

Evolution faces a tough dichotomy to get around if multicellularity is to evolve: cellular selection vs organismal integrity. At the single cell level, selection will favour cells that reproduce better. But if those cells are allowed to reproduce uncontrollably in a multicellular organism, they will inexorably destroy organismal integrity, and harm or kill the organism, also causing the 'fitter' cells to die.[13]

At the organismal level, selection will favour traits that preserve organismal integrity, which tries to control reproduction of cells beyond what is needed. Pepper *et al.* agree:

> 'Multicellular organisms could not emerge as functional entities before organism-level selection had led to the evolution of mechanisms to suppress cell-level selection.'[14]

However, this leads to a mystery for the evolutionist: how do multicellular organisms evolve from single celled creatures when cellular selection and organism-level selection are *totally contradictory* to each other? The multicellular organism seeks to control the reproduction to what is needed at a higher level of organisation; a single cell seeks to reproduce more than its competitors.

It appears that mechanisms for apoptosis (programmed cell death) are necessary for multicellularity, whereby certain cells are triggered to die during development or because they have gone haywire. Such mechanisms are incredibly complex and arguably irreducibly complex.[15] Explaining the existence of such a mechanism without intelligent design seems to be a futile exercise.[16]

Co-operation and colony: halfway there?

Co-operative and colonial organisms are proposed to be the route through which multicellularity evolved. Cooperative behaviour occurs in unicellular organisms. For example, *Salmonella typhimurium* can arrange themselves in two ranks for invasion—the first rank launches a suicide attack and the second rank slips through the confusion in the defence caused by the first wave.[17] Therefore, some communication between unicellular organisms occurs to allow for co-operation.

Many organisms form colonies. However, single cells in most of these colonies retain the ability to 'break off' from the colony when circumstances are favourable to doing so. Colonial systems have co-operation, but no regulatory system to force the cells together as a unit of selection in its own right. Moreover, a colonial organism can be pulled apart without

significantly damaging it, unlike a multicellular organism, which will be severely injured or die if pulled apart. Michod *et al.* concur:

> 'Such associations and groups may persist and reform with varying likelihood depending on properties of the group and the component individuals. Initially, group fitness is the average of the lower-level individual fitnesses, but as the evolutionary transition proceeds, group fitness becomes decoupled from the fitness of its lower-level components. Indeed, the essence of an evolutionary transition in individuality is that the lower-level individuals must "relinquish" their "claim" to fitness, that is to flourish and multiply, in favor of the new higher-level unit.'[18]

Some colonial organisms, however, do appear to be obligate and show some specialisation, such as some members of the Volvolaceae family, like *Volvox carteri*. The point at which colonial organisms fail as true multicellular organisms is their lack of division of totipotency[19] and 'immortality':[20]

> 'The un-coupling of immortality and totipotency proved not possible in *V. carteri*: these traits are express either together and fully (i.e. in the gonidia) or not at all (i.e. in the somatic cells). Immortality and totipotency are thus still tightly linked in *V. carteri*, as they are in their unicellular ancestors. In support of this view is the fact that "cancer-like" mutant somatic cells, in which immortality but not totipotency is re-gained, are missing in *V. carteri*. There are, however mutant forms of *V. carteri* … in which somatic cells re-gain both immortality and totipotency, but in neither of these mutants are the two traits expressed partially or differentially (e.g. limited mitotic capacity or multipotency).'[21]

This means that differentiation in the colony could only extend to two different types of cells and no further. Because they are unable to split totipotency and immortality, volvocine algae cannot create new somatic cells, and are as a result unable to survive for very long as an organism. In other words, there are no maintenance or repair strategies in volvocine life forms, so they lack one of the essential features of true multicellularity.

Opportunities for further research

I've here tried to present some basic requirements that must be met for the evolution of true multicellularity. For true multicellularity there has to be genetic sameness among all participating cells. Intercellular co-ordination serves as another level of organisation in life that can't be reduced to the sum of its parts. There is a 4-level hierarchy in the regulatory architecture that must all be there for a viable developmental plan to proceed. Repair and maintenance requires one or more pools of undifferentiated, generally multipotent, stem cells. Cellular selection and organismal integrity remain diametrically opposed, and provide a very tough problem for evolution to overcome. Colonial unicellular organisms don't fit the bill as multicellular creatures because of the difference between of their lack of this 4-level hierarchy, and the lack of maintenance and repair mechanisms for the organism.

This is a neglected area of creationist research, where there are a number of opportunities for further investigation.

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7. *Plug-ins* are common subcircuits that are utilized for many different developmental functions.
8. *Input/output linkages* are regulatory controls on the same stand of DNA as the gene they work on either switching them on or repressing them, depending on the developmental situation.
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