Abstract for "Individuals Across Sciences: A Revisionary Metaphysics"
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"A continuum of individuality in modular organisms"

From an ontological point of view "individuality" is generally assumed to obey the law of the excluded middle: something is either an individual or it is not. However, from the point of view of biology, we must employ a concept of individuality according to which being an individual admits of degree. Although many biologists use the criterion of genetic homogeneity to define an individual organism, Folse and Roughgarden (2010) have argued for the evolutionary criteria of alignment of interests of the parts, export of fitness from the level of parts to the level of the whole by division of labor, and adaptive functional integration. By any of these three criteria, many organisms display an *intermediate degree* of individuality, demonstrating that individuality is not an all-or-nothing trait, but rather a continuum.

Organisms in which individuality comes in varying degrees include colonial invertebrates, clonal plants and algae, colonies of social insects, mycelial fungi, slime molds, and other multicellular aggregates of microbes, which include a significant proportion of the tree of life. A key characteristic shared by many of these organisms is their modular structure. That is, the whole is formed by the iteration of similar (often genetically identical) units called modules, which are semiautonomous yet integrated to form the whole. The greater the degree of differentiation, integration, and interdependence of the parts, the greater the degree to which the whole functions as an individual. In unitary organisms such as humans and other vertebrates, the various parts of the body are highly differentiated, integrated, and interdependent, and thus we have no difficulty identifying a human as an individual. However, the branches of a tree are less differentiated, and only loosely integrated and interdependent. In clonal plants, such as strawberries, which grow by the production of lateral stems called runners which then send up new modules, there is only minimal differentiation, integration, and interdependence between modules. Therefore, we can say that a tree is an individual to a lesser degree than a human, but to a greater degree than a patch of strawberries.

In modular organisms, somatic mutations can introduce genetic heterogeneity between modules, in which case both the parts and the whole can act as units of selection, leading to multilevel selection both within and between organisms. Selection at the lower level is typically viewed as a threat to the integrity of the individual at the higher level, as it is when selection acts discordantly across levels, as occurs in cancer, germ cell parasitism, and "stalkless" slime molds (Buss 1982). However, in other cases, selection acts concordantly between levels, for example when germline selection reduces genetic load by removing deleterious mutants and promotes the retention and spread of beneficial alleles (Otto and Hastings 1998). Furthermore, there may be direct benefits to the higher level of including genetic heterogeneity at the lower level, as in plants, where genetic mosaicism may protect them against herbivores (Whitham and Slobodchikoff 1981), or in

honeybees, where genetically diverse colonies forage (Mattila and Seeley 2007) and control temperature (Jones et al. 2004) more efficiently.

Recently, Folse and Roughgarden (2011) have demonstrated in simulations that selection at the module (branch) level within long-lived trees allows the tree to adapt to its local herbivore population, and reduces local adaptation of the herbivore to the tree. Furthermore, when viewing the modules of an organism as individuals, the sexual lifecycle can be reenvisioned as a sexual/asexual lifecycle (Hastings 1991), in which repeated rounds of asexual reproduction are interspersed by occasional sexual reproduction. The model demonstrated that this lifecycle gives the plant an advantage in coevolution with a sexually-reproducing herbivore, because beneficial combinations of alleles are not broken up (Folse and Roughgarden 2011). In summary, the recognition of intermediate degrees of individuality existing simultaneously at multiple, nested levels has led to important biological insights that are obscured by a simplistic all-or-nothing concept of biological individuality. Therefore, in order to be successful, any general, synthetic concept of individuality must take into account these complexities.

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