Canalization and environmental engineering

Hajime Yamauchi

Japan Advanced Institute of Science and Technology
hoplite@jaist.ac.jp

Canalization is an umbrella term a leading C. H. Waddington introduced in 1960's. The term describes the ability of a population to buffer disturbances in phenotypic development. There are two major types of canalization based on the sources of disturbances: genetic and environmental. Genetic canalization describes the ability to express the same phenotype from different genotypes, while environmental canalization is to stabilize development under different environmental conditions.

With a graph of norms of reaction, evolutionary process of canalization is expressed as a squashing process of the pattern of phenotypic expression across a range of environments. It is also known that learning (or plasticity, in general) has a similar effect: it would normalize the end state of phenotypic development. However, it has not been thought of a case of canalization as it also enables a genotype to express two distinctive phenotypes (as the term "plasticity" implies).

In this work, we will challenge this view, and examine how learning would potentially provide a third type of canalization. Specifically, this work will show if phenotypic traits are partially inherited via cultural transmission (i.e., learning), and if the function of the trait is to do with social conformities among individuals in a population, it would possibly stabilize the learning environment itself so as for different genotypes to be able to express the same phenotype. This effectively narrows the range of trait variation not by (evolutionarily) modifying the reaction norm itself, but by manipulating the variation of environment the majority of the population would encounter during its learning period. As such, this type of canalization should be categorized neither genetic nor environmental canalization.

We use a multi-agent model which simulates evolution of language. In the model, the population consists of 200 agents allocated on a horizontal space. Each agent acquires her linguistic knowledge with inputs provided from adults' linguistic activities (i.e., communicative activities). Learnability of given linguistic knowledge is sensitive to 1. learner's genetic information, 2. learning ability, and 3. consistency of inputs across different adults. The fitness of an agent is measured by the number of successful communication with her neighbor peers.

With the condition that there is no evolution on the learning ability, the result shows that initially, selection works on genes so that agents' genetic information conforms with the linguistic knowledge dominating the population, as this eases the burden of learning —a classic example of the Baldwin effect. However, as doing so, the population more and more converges into a single linguistic community. This paves the way to smoothing the learning environment (i.e., the collective state of learning inputs) from which later generations learn. Consequently, the environment is now confined itself to provide coherent inputs. Under this circumstance, the population can tolerate a certain degree of genetic disturbances as they can be absorbed by the plasticity which created such an environment itself.

As noted above, this type of canalization is primarily not a process of genetic evolution. Instead, it is an environmental engineering process which modifies the frame of norms of reaction itself.