7.2 Reorganization

Somehow or other, the output of an ECU must act on the environment in a way that influences its perception, and influences it in the direction that reduces the difference between the perception and its reference. Moreover, since the objective, from Mother Nature's impersonal viewpoint, is that the organism survives long enough to propagate its genes to its descendants, controlling this perception rather than another must serve to keep the important life functions operating smoothly. Powers called the variables affected by these life functions "intrinsic variables". Their maintenance in relationships that help the organism survive is the evolutionary point of control. If controlling this perception helps, it is likely to be stabilized within the organism's repertoire of controlled perceptions, and its quality of control becomes as important as does the maintenance of any of the physiological intrinsic variables.

We first address reorganization as a way to develop good control of some perception or other, ignoring for the moment the maintenance of the relationships among the intrinsic variables. Madly flailing about and smashing everything will probably influence the perception in question, but not in a way that is likely to improve the chances for long-term survival of the organism or the propagation of its genes. Nor is a general rampage any more likely to reduce the error value in the ECU than it is to increase the error. Indeed, since the rampage will inevitably disturb the values of perceptions controlled by other ECUs (side-effects), usually increasing their error and requiring their countervailing action. In short, rampaging is usually counter-productive. Yet many children and some adults do have episodes we call "temper tantrums". Why would this be? To answer this question we ask how the functioning of a partially constructed control hierarchy can be altered by reorganization.

We hinted at reorganization when we were adding a higher level of 6 controllers above the 36 that control the orientations and locations of parts of the chair. The six controllers will not be very useful if their connections to the lower-level controllers are random. Reorganization changes the influence of any one upper-level output on each of the lower-level reference values, and likewise for the upgoing perceptual signals used as inputs to the higher Perceptual Input Functions. Reorganization adapts these interconnection influences so as to improve the upper level control quality.

Reorganization is the equivalent of "trying something else" when what you are doing isn't working. Randomly "trying something else" would take a very long time to produce a useful result in a complex system, but "trying something else" need not be random; Powers (2008) described an effective reorganization algorithm known conversationally as "e-coli" because it was conceptually based on the movement of the e-coli bacterium.

The bacterium (at least when taken as a model of the reorganization process) moves more or less in a straight line through a chemical gradient until it comes to a place where the desired concentration begins to decrease, at which point it "tumbles" and starts moving in a new randomly chosen direction. If that direction turns out to be down-gradient, it immediately tumbles again. Similarly with reorganization. The pattern of connections among the ECUs at different levels is taken to be a location in a high-dimensional space, so the direction of "movement" is represented by a vector of weight changes. So long as control improves, the same direction of weight changes is retained, but when control begins to get poorer, a new random "direction" of weight changes is chosen. Powers demonstrated the effectiveness of the technique in a space of 14 higher-level controllers in a demonstration called "Arm 2" that is included with LCS III (Powers 2005).

The actual brain mechanism of reorganization is unknown and unimportant for the discussions in the rest of this work (one kind of possibility is described in Appendix Ax9). One may, however, presume that reorganization involves synaptic modification, and in Chapter 6 we hazard a guess at some possibilities as to how this might implement at least some of the e-coli reorganization process described by Powers.

E-coli reorganization is quicker to change control connections that do not work than those that do work, but does not leave totally untouched even controllers that are working well. The result is what is sometimes called a "winter leaf" effect. Fallen leaves get blown around by gusty winds until they pile up in some relatively calm place under a hedge or in a corner. A reorganized control structure contains control units that have worked and continue to work together in the environments in which the organism (person) has learned to control. If reorganization changes them so that they work less well, they are likely soon to change back again, or at least to a better state. Crudely, reorganization approximates the mantra "*If it ain't broke, don't fix it*", but occasionally does fix something that ain't broke.

In this context, we must deal with the issue of "carrots and sticks". A "carrot", according to PCT, is something of positive worth, that improves control of some perception, not necessarily or even probably the one for which the carrot is offered. "If you mow the lawn, I'll give you $10." We deal with this kind of transaction when we talk about barter and trade at the end of Part 2 of this book. PCT does not treat a "carrot" as a reinforcement. As far as reorganization is concerned, the "carrot" simply indicates that control is working well. The "e-coli" principle therefore says says that if there had been ongoing changes, to continue to change in the same direction.

"Sticks" are different. A "stick" is a disturbance to a perception that is not currently experiencing much, if any, error. A "big stick" is such a disturbance applied in a manner that cannot be corrected by the controller using the means at hand. It is usually called "punishment", and because it produces a state of sustained error in the control of some perception, it is likely to be accompanied or followed by an increased rate of reorganization.

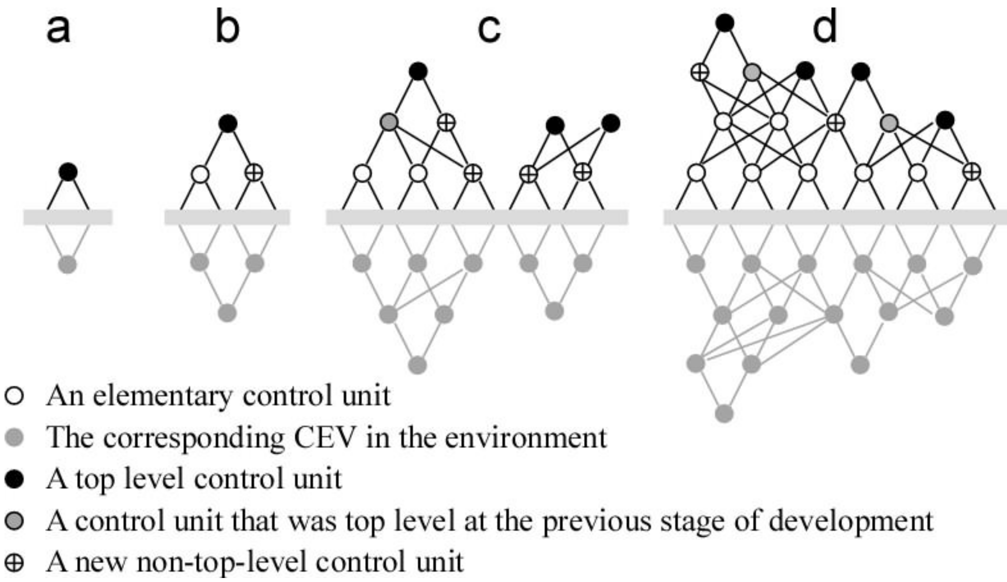
The problem for the one using the big stick is that reorganization can have quite unpredictable results. The one being punished may have been controlling for a wide variety of different higher level perceptual results, using atenfels that involved the "punished" actions. The ways that those higher levels can be controlled are usually numerous — "*many means to the same end*" — and not all of them would fail to disturb some variable the punisher might be controlling. In plain language, the punishment intended to make the evildoer see the straight and narrow might instead turn him into a rebel. It can achieve the punisher's immediate intention, but unless the punisher also guides the evildoer to find an acceptable way to achieve the higher-level goal, the probability that he will is rather low. We saw a similar issue when we discuss the perception of "not" and the problem of avoiding having an unwanted value of a perception in Section 5.9.

Reorganization has a second aspect, the perceptual side of the hierarchy. On that side, which the chair example illustrated, reorganization uses the principle of "*If controlling this doesn't help, maybe you can see things differently*" to go along with the output-side mantra of "If it ain't broke, don't fix it". Perceptual reorganization has seldom been addressed in PCT discussions, but it is important that the organism should be able both to generate novel perceptual functions when the environment changes, and to be able to recycle into new forms perceptual functions that generate perceptions whose control uses energy without benefiting the intrinsic variables.

As a control hierarchy matures, whether it be in a human, a tree, a bird or a fish, the higher levels cannot develop effectively unless the levels below control their perceptions at least moderately well. If the 36 lower-level units acting on the parts of the chair did not control their perceptions very well, the six higher-level ones could not. Indeed, the higher-level units probably would never be formed, since the patterns of perceptual values and effects of outputs to the lower-level references would be quite inconsistent. Nothing would then be controlling "chair-object perceptions" as opposed to "chair-part perceptions".

The ability of a control system to oppose the effects of disturbances and have its controlled perception reflect changes in its reference value is limited by the stability of the effect it has on its CEV. If its influence on, or its perceptions of, the environmentally constrained collection of properties constituting the CEV of a well controlled perception keeps changing character, it will control badly. The effect of a higher-level controller on its CEV is actually implemented by the actions of lower-level control systems controlling their perceptions to reference values responsive to the higher-level systems. If those lower-level systems are unreliable, the higher-level systems will be unstable or worse. In the end, reorganization can develop control systems only to as many levels as will allow the effects of changes in organization to improve both control itself and the effects of control on the intrinsic variables that keep the organism alive.

The apparent consequence of this is that early control will be best in a stable environment, which allows new, higher levels of control to be built on top of stable lower-levels, as suggested in 7.5. Later, these higher levels will continue to operate for as long as the lower levels maintain good control, and at the same time new perceptions at existing levels may be built, forming new "top-level" control sub-hierarchies, as in 7.5c and d.



7.5 A developing control hierarchy builds control of ever more complex perceptions (with correspondingly complex environmental variables) onto previously reorganized control units. A "top-level" unit is one that receives no reference input from any higher-level unit. For example, in Panel d, there is a top-level unit at level 2, two top-level units at level 3, and one top-level unit at level 4. The grey mirrored structures below the line are the "mirror world" created in the environment by the developing hierarchy.

In the Figure, panels a–d show successive stages in the growth of a simple control hierarchy. Van Rijt and Plooij (1992) studied the development of successive levels of perceptual control in the growing child, and showed that well-defined changes of behaviour can be observed when each new level is achieved. The Figure illustrates that "top-level" control units do not always have to be at the same level.

The observations of Van Rijt and Plooij suggest that perhaps there is a mechanism that facilitates the development of new instances of a control unit at a level once the first instance has been created. An analogy might be the easy creation of new instances of an object class in Object-Oriented-Programming (OOP) once the class has been programmed, though of course the method of creating a new instance of a type of ECU cannot be anything like the method of creating a new programming object!

Living in an environment that is too stable does not lead reorganization to create versatile systems that can control in changing environments. In the stable environment, the system need not use "many means to the same end" because one "means" is enough. It becomes rigid, and might be perceived by an external observer as being bound by habit and ritual. In 7.5, the more connections a unit has to the levels below, the more flexibility it probably has to control its perception in different contexts. The child learns to walk to a friend's house, but later learns how to ride a bicycle, and can use either technique to control for perceiving herself to be at the friend's house.

As the system grows new levels ever higher in the hierarchy, each new high-level perception must initially depend on only those lower-level perceptions that first are connected as inputs into its perceptual function, and can act only through those lower-level controlled perceptions to whose reference function inputs it is first connected. Every new high-level system is rigid, in that it has just one way to control its perception, even though it acts through lower systems that may have developed multiple ways to control their own.

As they add levels to their control hierarchy, children often have phases in which they insist on doing things by the rule-book. It is just "the right way to do it" and if an adult "does it" a different way, the child may object. "Mummy always hangs her coat up on the door. Why are you putting yours on the chair? You shouldn't do that. It's wrong." These are ideals, reference profiles for different levels of control below the level at which the overt intent (putting the coat in a convenient place) exists.

"Idealism" implies a reference profile for "the way the world should work". It is a concept that can be applied at several levels of the Powers hierarchy. If 2+2 is the problem, then ideally, the answer should be 4. When a child begins to learn arithmetic, perceptions of such problems provide clear reference values for providing the answers. But as the child learns more, 2+2 often does not mean 4. As President Clinton might have said: "It depends on how you define 2". In mathematics, if your addition is modulo 3, then 2+2 = 1. Geometrically, if in a curved space you go 2 units and then another two units in the same direction, you may well not be 4 units from your starting point. You might even be back where you started, if the unit is ¼ of the circumference of the Earth. Think of the old riddle:

"*You walk ten miles due South, then ten miles due East and ten miles due North, arriving back where you started. You meet a bear. What colour was the bear*?"[1]

But if the only geometry you know is in Euclidean space, and the only arithmetic you know is what you learned in grade school, then 2+2 must equal 4 both numerically and as a distance from your starting point. Furthermore, no triangle can have three equal sides with every corner angle being 90°, a perfectly reasonable possibility for a triangle on a sphere. Idealism at a perceptual level tends to evaporate when one has reorganized to be able to control perceptions in a variety of contexts.

If this "one way first and then become flexible" sequence is a general property of growing levels in the hierarchy, rigidity at a level is likely to last longer the higher up the hierarchy we go. When we come to system-level perceptions such as political or religious systems, flexibility may develop very late, if ever. Even though a prophet may have had many ways to control certain perceptions and been very flexible in his means of control, later followers often are very rigid in their requirements for formal rituals, behaviours, or clothing, and consider them, rather than understanding the prophet, to define the religion.

Rules, independent of context, may persist for a lifetime, but are likely to be evident for some while in nearly all people as they approach adulthood, because the higher levels are likely to

1. White. It would have been a Polar Bear.

develop more slowly than the much-used lower-levels. These rules form the "ideal" way to achieve the (fixed) reference value for a top-level structure. If the "ideal" consists of, say, obedience to authority in the Confucian sense, then criticism or, or failure to obey authority might result in appreciable error in the controlled system-level perception. The same would be true if the "ideal" included a requirement for "fairness" and the person perceived the behaviour of others (or herself) to be unfair. Error in a control unit leads to action if the perception is being actively controlled.

Error in a unit that acts only through a rule-based (single-means) output structure may sometimes prove uncorrectable despite violent activity directed at correcting it. Such would be the case if a dominant authority is perceived to be unfair and the person has no atenfels for influencing that perception. That kind of perceptual error is hard to correct, and any action taken to correct it is likely to be seen by the authority (parent or public figure or institution[2]) as an unfocused temper tantrum or a directed rebellion to be suppressed by force.

Reorganization, however it functions, fits the maturing organism to survive and, with luck, prosper in the environment in which it lives. If that environment consists of mechanical and biological servants that attend to its every wish, it will learn to function by ordering its servants. If it lives alone in a jungle, it will learn how to identify ripe fruit and avoid those that make it nauseous, as well as learning how to avoid or outfight predators. In a city, it may learn how to navigate traffic, techniques of shopping or stealing, and so forth. Every environment demands different sets of skills, and any species that has few descendants per parent must either be found in a restricted environmental niche, or be capable of wide-ranging adaptation — sufficient reorganization in a lifetime to control its perceptions effectively for the maintenance of its intrinsic variables in many environments. Humans are the adaptable species *par excellence*, and may reorganize in a wild variety of ways.

Two properties of reorganization are important. Firstly, perceptions must be controllable, and secondly, the perceptions to be controlled should be those for which control serves to enhance the organism's survival to propagate its genes. As we shall see, this latter requirement leads usually to socially adapted behaviour, in which members of a culture are more likely to try to help than to hurt one another.

Next,we speculate about how reorganization can become effective and efficient, in part by working not on the entire hierarchy of perceptual control as a unit, but by treating small modules that are then reorganized as units in higher-level modules. We start by examining the e-coli reorganization process a little more closely.

7.3 Modularity of Reorganization

Reorganization using the e-coli process will work, but if there are a lot of parameters to be altered it may work very slowly. Mathematically, the issue is that each parameter in the control hierarchy may represent an independent dimension in a space of extremely high dimensionality.

2 We treat the possibility of institutions acting as control systems in Part 4 of the chapter.

When a “tumble” occurs in an e-coli hill-climbing procedure, the new direction of change can be described by the rate at which each of the parameters is changing, which stays constant until the next tumble. Some directions result in improved intrinsic variable function, some in reduced function. The chance is about 50-50 which way it will go.

The problem is that in a high-dimensional space almost all random directions are nearly orthogonal to any pre-specified direction, such as the direction toward the optimum set of parameter values in the space. If there is any random variation, such as an external disturbance, changes due to that variation will act as “noise” that makes it difficult to tell whether the underlying change in parameters improves the situation or makes it worse. One way to resolve this problem is to increase the rate of tumble if the rate of change in the intrinsic variable function is too close to zero. Of many tumbles in quick succession, maybe one of them will result in appreciably better function of the intrinsics variables.

But what if the current parameter set is very close to optimum? If that is the case, almost every tumble will make things worse, or at least not detectably better, and the direction would tumble very often without much effect. Another solution must be found. That solution is modularization. Modify only a few parameters together, and then modify the parameters in that group together, treating each of a small number of modules as individual elements that have their own set of parameters. Does this sound like what happens with control of perceptual complexes in Section 4.9? It should, because exactly the same principles are in play, coordination of change using modularity of effect.

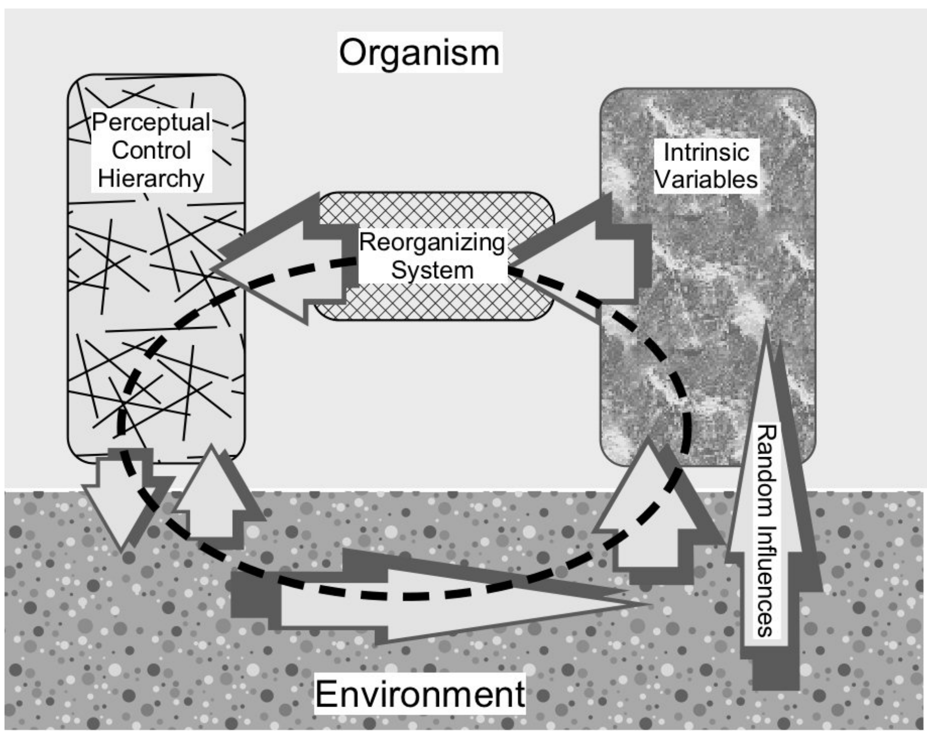
In Appendix X9, I show how a trivial example of reorganization can take the form of an explicit control loop. In the example, Quality of Control by a simple “subject” control loop is the controlled perception, and variation by Powers’s e-coli process of the parameters of the subject loop are the output. Thinking of control in the abstract, as manipulation of the environment to structure it in a way most congenial to “happy survival” of the organism, the whole perceptual control hierarchy can be thought of as the environment of a different control hierarchy, the reorganization system.

In Section 4.9, the consistent real-world effects of moving a chair created correlations among the perceptions of its legs, seat, and back. The environmentally created consistencies become reflected in the construction of modular components of the perceptual hierarchy, namely the “chair” perceptions together with their component “chair-part” perceptions. Might we not expect something similar of a reorganization system, whether its components are perceptual control units or something else entirely?

There is a problem with this question. For the perceptual control hierarchy, the consistencies are imposed by the real environment, not just the environment we perceive. We may not notice that this “chair-back” moves in a way coordinated with that “chair-leg”, in that we may not construct a perceptual complex that combines them, but that consistent relation nevertheless exists in the real world. We do not perceive gamma radiation, but if we are exposed to too much of it, we die. The “real world” is “boss” as Powers often noted in on-line discussions.

For the reorganization system, its environment is the eminently malleable perceptual control hierarchy. Indeed its very job is to change the perceptual control hierarchy, so its local environment is not its boss. What is, if anything? What else but the system of intrinsic variables that determine our well-being and our very survival? These are intricately interconnected in ways that have been determined by evolution through our ancestors who lived in the "boss world" as it was structured in their lifetimes. Intrinsic variables do not maintain themselves simply by internal homeostatic mechanisms, but are subject to the "slings and arrows of outrageous fortune" — entropic decay — just as much as are any other parts of our structure. To reduce or avoid these "slings and arrows" is the reason for perceptual control.

Our controlled perceptual variables generally correspond to environmental variables we have called "Complex Environmental Variables" (CEVs). To set a CEV to a particular value, however, is not the same as to adjust an intrinsic variable. Perceptual control affects intrinsic variables only through side-effects of control, which include the effects of any changes in the CEVs. But in these side-effects we have the way that "boss reality" provides the reliable structure within which all organisms have evolved from the earliest days. Error in the intrinsic variables leads to reorganization of the perceptual control hierarchy, the operation of the perceptual control hierarchy affects the environment, and effects in the environment influence the intrinsic variables in a "Grand Loop" that is reminiscent of a control loop (7.6).



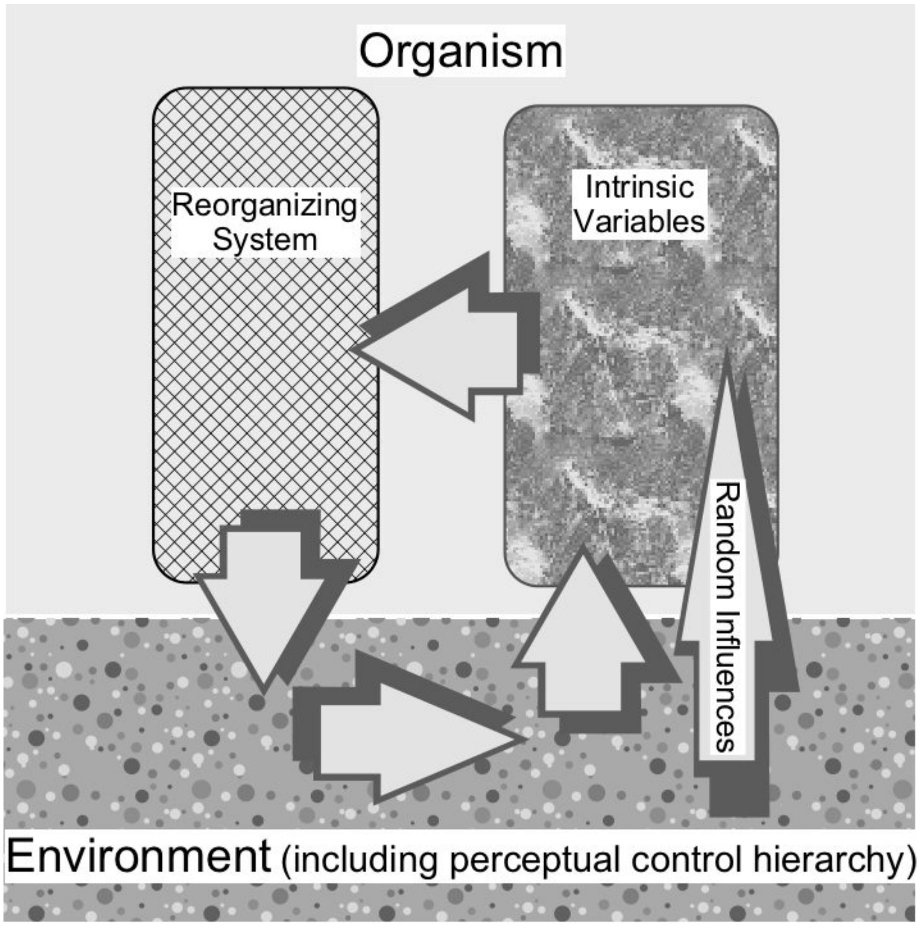
7.6 The "Grand Loop" that allows an organism to survive in a complex environment. Organisms without a reorganizing system would either be short-lived or would be well armoured and live in a stable environment. Otherwise the species would survive by providing each entity with large numbers of descendants, very few of which would survive to propagate further generations. The place of reorganization in the Grand Loop would be taken by evolution.

At a very basic level, "boss reality" contains the physical constants that we presume to have remained stable throughout the life of the Universe. These determine what forms of matter and energy can exist, what atoms will be stable, what chemical molecules can form and how they interact, and so forth. On a shorter time-scale, such as the life of the Earth, the mass of the Earth and thus the force of gravity on an organism of given mass has not changed appreciably so long as there have been land-living organisms such as plants and animals that needed to counter it. As we consider shorter and shorter time-scales, more and more aspects of the environment seem to have changed hardly at all. Continental drift has affected the evolution of species, but not the forms of cultures, whether human, animal, vegetal or microbial.

But some aspects of the environment do change on shorter time-scales, even within the lifetime of an individual, and these changes influence the way the side-effects of perceptual control affect an organism's intrinsic variables. Either an organism must live in a stable environment and produce many descendants few of whom will survive to propagate further, or it must be able to reorganize during its lifetime to alter the side-effects of perceptual control in ways that continue to keep the intrinsic variables in good shape. "Good shape", now, refers to the way they were kept by our recent ancestors a few tens or hundreds of generations ago, in an environment that may not be ours. Reorganization must compensate for differences between our environment and theirs, as well as for changes in the environment during a lifetime.

Ignoring the species that do not reorganize during their lifetime, we can see two places in the "Grand Loop" that could have complex stabilities that potentially might influence the reorganization process. One is the environment itself, while the other is in the genetically determined "reference" stricture of the intrinsic variables that might be affected by influences from the environment.

To consider the implications of this, 7.7 simplifies 7.6 by merging the perceptual control hierarchy with the variables it controls in the external environment, since alteration of a reference value in the perceptual hierarchy is tantamount to changing similarly the value of a corresponding environmental variable.



7.7 The Grand Control Loop simplified. Seen this way, the whole structure has the form of a complex multi-variable control loop. The reorganizing system serves as an action component and the intrinsic variables as a perceiving component in which reference values for the variables have been provided by evolution.

In this simplified Grand Control Loop the reorganizing system acts on its environment through an interface that consists of altering the parameters and connections of the perceptual control hierarchy. These changes alter the perceptions that are controlled and the actions that are used to control them. If reorganization is effective, actions performed by the outputs of the perceptual control hierarchy will now influence some intrinsic variables toward their genetically determined reference values.

For example, an adult will work at a job to make money that can be used to buy food that when consumed will reduce perceived "hunger" (error in a satiety perception, presumably). As a side-effect, energy becomes available in chemical form for the operations of the cellular system, such as the brain, the muscles, and all the rest of the body, little or none of which is directly available as a perception in the perceptual control hierarchy.

In a system reorganized in a different environment, an adult will go out into the bush with a weapon to kill an animal that he will take home and eat, or he may go into the forest and pick fruit to eat. The office worker who has never seen bush or forest might starve or be poisoned in that environment until the error in his intrinsic variables induced some reorganization.

If we accept the idea that the Grand Loop has the function of a control loop, then perhaps we can pick it apart in much the way that Powers did for the control hierarchy, treating each perceptual variable not as a complex but as a simple scalar variable represented in the brain by a neural firing rate. In Section 4.9, we used the "Chair and parts" example to illustrate how this approach combines with structural aspects of the "boss world" to generate modular perceptions. We might well expect the same of the reinforcement system. It may be up to evolution to define the intrinsic variables for each organism, but reorganization defines the perceptions and actions in the perceptual control hierarchy, and they are modularized by the structure of the environment, physical and social.

The environment is not alone in having internal structural and dynamic relationships. The many intrinsic variables do, too. Physiologists have found many interactions among them and discover more every year. These structures will be "rigidities" (analogous to the relationships among the parts of the chair of Section 8.1) that determine what kinds of reorganization of the perceptual control structure will improve the states of the intrinsic variables[3]. Now we can call this improvement "reduction of error", just as we use reduction of error to assess Quality of Control (QoC) in the perceptual control hierarchy.

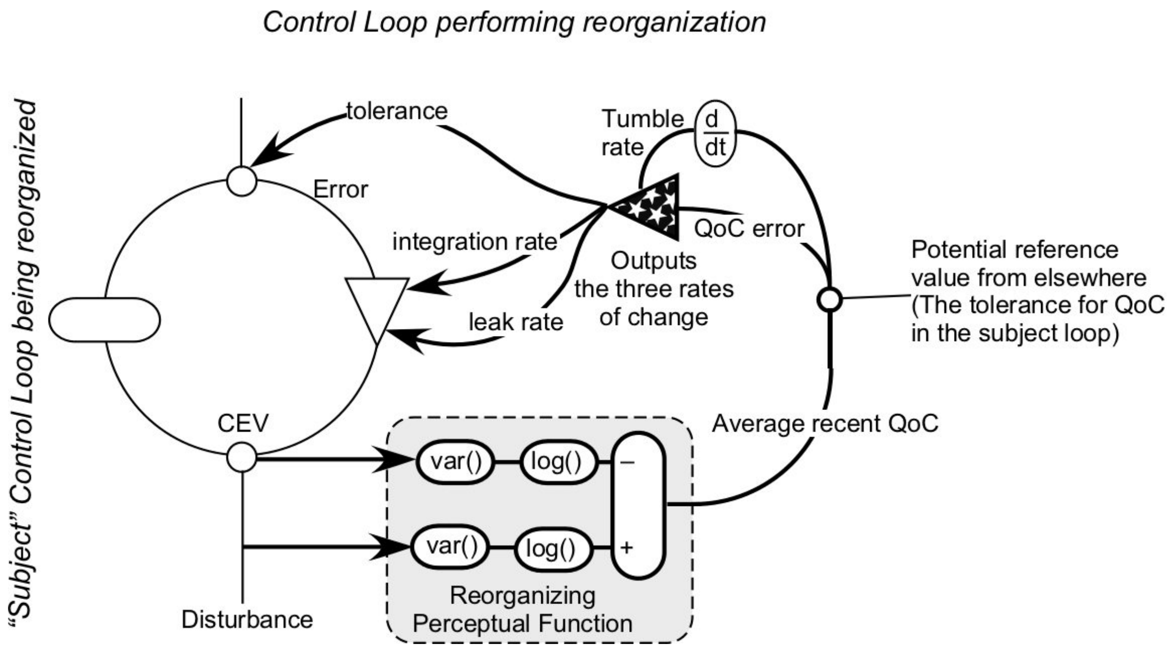
The reorganizing system thus seems to be "squeezed" between the structural properties of the environment and the structural properties of the intrinsic variables. The reorganized perceptual control system would be most effective if it took advantage of both, which means the reorganizing system must create perceptions that are useful to control and actions to control them that have side-effects that tend to reduce the errors in the intrinsic variable system.

Because of the structural regularities or rigidities on both sides of the reorganizing system, we should expect it to have structural levels analogous to the levels in the perceptual control hierarchy. In such a structure, reorganization of the local neighbourhoods of single control units might be analogous to perceptual control influences on the smallest perceptual elements. Together with any parameters relating to a particular loop's connections with higher and lower level control units, a second-level reorganization loop might act analogously to the "chair-level" perceptual control to improve coordinated performance. If this idea is extended, one might conceive of a reorganization hierarchy devoted to improving QoC throughout the perceptual control hierarchy, regardless of what perceptions are actually being controlled.

One thing we might expect of the reorganizing system is that its smallest modules enhance the QoC of control units in the perceptual control hierarchy. A perceptual control unit that does not control well will have inconsistent side effects, quite apart from any differences that might result from changes in its mode of control, such as choosing to walk to work instead of taking the car.

3. Later, such as in Section 8.5 and scattered elsewhere, we will treat both kinds of rigidities as analogous to "rods", the compression components of physical tensegrity structures.

7.8 suggests a possible reorganization control loop that reorganizes the parameters of a minimal perceptual control loop so as to optimize its QoC. The subject control loop has three parameters: integrator gain rate, integrator leak rate, and width of the tolerance zone. This problem is a simple hill-climbing optimization in three dimensions that might well have an analytic solution, but we here use it as an illustration of a general process, e-coli reorganization. 7.8 suggests one possible structure of a reorganization control unit.



7.8 A possible reorganizing control system that has as its perceptual variable quality of control in the "subject" loop being reorganized and as its output rates of change of the three parameters of that loop. The output function produces these rates of change by "tumbling" to a random direction at a rate determined by the current QoC.

In 7.8, the three parameters of the subject loop must have rates of change that are very slow compared to both the rate of change of the disturbance and the time it would take the loop to counter most of the change in the CEV induced by a step change in the disturbance. The heart of the reorganization loop is the output function that determines what these three rates of change must be, and when to change them — when to "tumble".

The perceptual function and the output function are the critical elements of any control loop, and the reorganizing control loop is no different. In 7.8, the reorganizing perceptual function is shown as the difference of the logarithm of the variances of the disturbance and the CEV of the subject loop.[4] The computation of these variances must incorporate a considerable period of time during which the subject loop is controlling, but with more recent values weighted more heavily than long-ago values. In life, there would presumably be no actual computation, but we can assume that some biologically feasible process produces a similar result. The output of the

4. In Chapter 7 we learned that this process measures the uncertainties of the two variables.

perceptual function is a measure of the average recent QoC, a variable we want to bring to some level within the tolerance of the reorganizing system by varying the parameters of the subject control loop.

The output function has to produce an output vector consisting of the rates of change of the parameters. This vector has a constant direction in the parameter space until a tumble occurs, after which a new direction is taken. The vector has a magnitude that determines the overall rate of change of the parameters, which the output produces in the normal manner of a control loop, by using the QoC error as the input to a leaky integrator that has the vector magnitude as its output. When a tumble occurs, the magnitude of the vector does not change, but its components are redistributed among the parameter change rates.

The rate of tumbling is a function of the rate of change of QoC, being low when QoC is increasing and high when it is decreasing. If it is unchanging, the tumbling rate is above zero, which allows the loop parameters to escape from a local minimum. Just what the function should be remains to be determined. Only qualitatively can we assert that the greater the proportional reduction on QoC, the less likely a tumble will occur within the next small time interval. Put another way, the survival probability of a direction decreases with time no matter what happens to the QoC rate of change, but it decreases faster if the QoC is deteriorating than if it is improving. Whether this rate is also a function of the absolute QoC is a matter for experiment.

This would not produce the best results for the intrinsic variables, because it would work independently of what perceptions might be controlled other than that they take advantage of structural complexity to control well. Only the question of whether controlling these perceptions is likely to reduce error in the intrinsic variables will affect their reorganization. Hence, we might expect reorganization of perceptual functions and the development of new perceptions to depend more on structural regularities in the intrinsic variables, and the reorganization of the action outputs of the perceptual control hierarchy to depend more on structural regularities in the environment.

Much of this is purely speculation, and none of it is provable. But the speculation is based on general principles, so we might call it an "envelope assessment" in the same way that limits on energy flow provide an "envelope assessment" of how fast a runner might run or a stevedore shift loads on a dockside. Details may be wildly wrong, but the general idea may nevertheless prove valid no matter how the details change as the result of future experiments on real and simulated organisms.