Powers of Perceptual Control:

An Inquiry into Language, Culture, Power, and Politics

M. Martin Taylor
Martin Taylor Consulting
mmt@mmtaylor.net

We thought we understood everything
but then we got more data
and saw how naïve we were.
Malcolm Collins (quoted in Science 9 Nov. 2018, p626)

Every sentence I utter must be understood
not as an affirmation, but as a question.
Niels Bohr

The first principle is that you must not fool yourself.
And you are the easiest person to fool.
Richard Feynman

Volume 3

Collectives, Truth, Trade and an Invisible Rabbit

Come one, Come all.
Rattle and Jostle, Bustle and Hustle.
Buy and Sell, Wheel and Deal.
What is it Worth?

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This is a work in progress, and the Table of Contents may not be up-to-date.

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Introduction to Volume 3

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To start, I repeat a quote from McClelland (2020) that was used in Volume 1, because it forms a bridge between Volumes 1 and 2 of this book. In it, McClelland describes a form of infrastructure that was not specifically addressed in Volume 1 because it depends on social actions, collective control, and the stabilities produced by other people's perceptual control, all of which are topics important to Volume 2. Because Volume 2 assumes that the reader understands the basics of Perceptual Control Theory, at least as expounded by Powers in his many writings, of which Powers (1973/2005, known in this book as B:CP) is considered to be the classic reference, McClelland's discussion should be immediately intelligible whether or not you have read Volume 1.

> *The kinds of activities described as work in everyday language are activities that create stable feedback paths in a shared environment for the benefit of other people. The word* [work. MMT] *is also commonly used to refer to the kinds of activities that maintain these feedback paths in place. Thus, work activities produce some kind of environmental stabilization, the creation of some atenfel, molenfel, or molenex, which can then be used in controlling other perceptions. Manual workers create stable feedback paths by manipulating physical objects; they build things, make things, and clean things up. Agricultural workers produce fields of crops and confinements full of animals to be used as food. Transportation workers move truckloads of products from factories to stores, where sales workers make those products available to customers in exchanges with predictably structured protocols. Service workers manipulate and stabilize the immediate physical environments of individuals, including their dwellings and even their physical bodies, as barbers and hairdressers do. Healthcare workers attempt to stabilize the physiological functioning of people's bodies. Educators strive to turn out classes of graduates with predictable abilities and skills, people who can then be hired to put their skills to work creating various kinds of feedback paths for others. Government workers maintain stability and order for the community in a wide variety of ways, from removing trash to providing and enforcing laws designed to regulate commercial transactions and maintain public order, and thus preventing large disturbances that would make control of other perceptions difficult.*

The purposes of any given social structure are reflected in the work done by its members, that is, the ways they seek to stabilize some portion of their shared environment. Thus, we can classify social structures by the kind of work their members do: for example, families, ideally at least, stabilize a home environment for family members; schools aim provide stable flows of individuals with the tools to take action in predictable ways; businesses provide people with goods—objects that can be used as feedback paths—and services—routine actions that serve as feedback paths for controlling the perceptions of those who receive the services; and governmental structures are intended to prevent the kinds of disturbances to a shared environment that would make the work of other social structures more difficult.

Even workers whose work seems somewhat abstract must produce physically perceptible stabilities, which can then be used as feedback paths for controlling lower- level perceptions essential for control of the higher-level, more abstract perceptions that provide the ostensible objectives of their work. Administrators and business executives create feedback paths by organizing the routine activities of others into predictable and efficient patterns for getting the work of an organization done. Knowledge workers put words on paper or images on electronic screens in order to send symbolic messages to others, thus facilitating their readers' control of higher-level perceptions. Entertainers offer their performances hoping to attract audiences, who will then use the performances as feedback paths for controlling perceptions of excitement or amusement. In every case, the creation of some perceptible product in the form of stabilized portions of the physical environment or stabilized patterns of human action—in other words, atenfels, molenfels, or some combination of them—provides the empirical evidence that work has been done. I argued above that these types of stabilities form the material and behavioral bases of social structures, and thus by producing these physical and behavioral stabilities people contribute to the overall stability of the social structures to which they belong.

In some kinds of work, people maintain feedback paths rather than creating them. People doing this work take the existence of certain feedback paths as perceptions to be controlled and then seek to protect them against the ongoing effects of disturbances. The janitor cleaning a building, the systems engineer fixing software bugs, the emergency responder driving an ambulance, or the baby's caretaker changing a diaper, all work to maintain feedback paths for others. Thus, the feedback paths in our shared environment depend on constant human attention and effort to do the work necessary to keep them stable. Without continual work, a humanly structured environment begins to crumble over time, like ghost towns or ancient ruins. The environments that most people live in are filled with feedback paths, both physical objects and routine actions, that have been shaped and maintained by human work.

Other than within a control hierarchy, we have considered control systems and loops either as isolated or as collaborating within a single larger structure that develops in ways that ease each other's work in

service of a higher-level goal, the survival of an individual organism. Social systems are not like that, at least not at first sight. Social systems consist of many individuals looking after their own interests as best they can amid a maelstrom of other individuals who are looking after their own very different interests.

Sometimes many individuals control their perceptions with a deliberate intention to cooperate in achieving a common aim. Sometimes their aims are incompatible, creating conflicts that can become deadly. Sometimes they are neither deliberately cooperative nor explicitly in conflict, but nevertheless the actions of many individuals controlling their perceptions within a shared environment may combine to create an environmental consequence that may be beneficial to some and harmful to others. At other times, the combined effects may create randomly fluctuating consequences, such as the price of shares of a particular publicly traded stock. The combined effects of adults talking among themselves and to a baby determine the language the baby will grow up to speak.

These and many other phenomena that occur when control systems interact are the subjects of Volume 2, but before we get to them we must lay a little groundwork. We have already talked about some emergent properties that arise from interacting control loops within a larger control hierarchy. Now we treat other ways in which interacting systems may generate emergent properties that depend on the interactions, not a summary or integration of the properties of the individual interacting elements. In Chapter 8, we called the Perceptual Control interactions that cause such emergent properties “Motifs” of control. In Volume 2 we will see more of them.

We start with consideration of more advanced topics of perceptual control in the individual, taking advantage of physical or chemical processes, particularly those involved with feedback loops, starting with autocatalysis and inventive creativity, homeostatic loops and cell structure, and entropy and energy relationships in control.

We next consider two novel approaches to organizational structures, “rattling” and “crumpling”, both of which have been studied as physical or mechanical problems, but which have important implications for control and specifically for the organization of both individual living control systems and social structures. Crumpling, in particular, is shown to have a deep relationship with category perception and the development of language.

After we consider the role of consciousness and emotion in reorganization, we step into the family world, beginning with the first mother-child language, and continuing with the development of informal language from an initial formal state, by using a multi-generational “family” of very simple caricatures of human beings. This leads into a general consideration of communication, whether among living organisms or between living beings and artificial entities such as computers.

Finally for this Volume, we expand from the family into somewhat larger groups, and consider the development of interactions for the same purpose by different people leads to the development of roles, which are simpler to learn than are personalities. We discuss several different forms of collective control and the possible benefits of side-effect loops that incorporate some conflict, before launching into the sociological ideas developed in Volume 3.

Part 7: Community, People in Larger Groups

We now begin to examine the implication of the main mantra of PCT "*All (intentional) behaviour is the control of perception*" when many people interact. We ask what perceptions may be controlled and how they may be controlled in collaboration with, or using the agency of, other people (or other control systems, more generally, since much of the discussion applies equally to non-human species).

It is obvious that people cluster in several different ways, by family, by clubs, by political belief, by language, by civic community or nation, as a revolutionary cell, and the list goes on and on. These groups overlap but usually do so without interference, in that an individual can belong to many of them at the same time. Problems can arise when individuals in one group belong to different groups of another kind, as, for example, if members of a family have opposed political beliefs. But for the most part, we can look at community structure as the same kind of fractal-like arrangement as the control hierarchy within an individual, and we argue that the same control phenomena, now in the explicit form of collective control, has similar effects in communities of individuals as it does in the communities of Elementary Control Units (ECUs) within an individual. Structures and overlapping modularities recur, for the same reasons.

To look at the effects of collective control in an individual, we return briefly to the syncon world, several generations removed from Len and Sophie. By this time, the cousins have split into distinct groups that speak different syncon languages. Marcel belongs to one group, but his travels bring him into a different one. We ask how Marcel and the new group accommodate to each other. This discussion leads to a more general discussion of control properties applicable to communities, under headings that include customs, rights and obligations, morals and laws, ownership and authority.

In Chapter III.2, we again examine autocatalysis and homeostasis, but in an entirely different domain of discourse. Now, the basic "reaction" is control of a perception by action on the external environment, and the "catalyst" is a side-effect of the control of some other perception. Side-effects come in two flavours, one being the direct effect of action on the some aspect of the environment that does not contribute to the perception being controlled, the other being the fact that some part of the environment is stabilized by control and becomes available for use by some completely different perceptual control system.

We argue that side-effect loops will occur if the population of controlled perceptions and actions is large enough, and that such loops are as productive as are the chemical loops described in Chapters II.1 and II.2. When enough side-effect loops have developed, the loops themselves could become elements in a higher-level autocatalytic network. We associate the development of successive levels of such loops with "revolutions", including punctate evolution, the development of language and language families, the Industrial Revolution, or the ongoing Technological Revolution, among others.

All of this may be bundled together under the heading of culture, so we discuss how cultures and their associated languages may drift apart or converge over time. The role of dictionaries as stigmergic arbiters or guides is important in stabilizing languages, as are laws and lawyers in stabilizing cultures, though neither form of stabilization prevents drift over time. Finally, we ask whether abstractions such as "culture" and "language" should be considered to be artifacts on a par with manufactured objects. We conclude that they should.

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Chapter III.1. Collective Control

We earlier hinted at the concept of “Collective Control” in the context of conflict and as a facet of the tensegrity structures of control. Now we examine various manifestations of collective control more closely.

Collective control operates both within the individual and among many individuals, so this Chapter serves as a transition between the discussion of the individual control hierarchy and the implications of perceptual control when several people interact.

The term “collective control” as used here has a specific meaning, the apparent control of a single environmental variable that makes the behaviour of the environmental variable seem as though it is the CEV of an ordinary controlled perception. Others have used the term in a wider sense, including the catch-all sense of any effects caused by the existence in a common environment of several different controllers, or the combined side-effects of many controllers controlling their individual variables. These are important questions, and the effects are sometimes hard to distinguish from true collective control, in which the control actions on different people directly influence the same environmental variable.

It is important to distinguish between true collective control, in which several controllers individually influence the value of some common environmental variable correlated with the CEV of a perception they control, as opposed to the combined influence on a single variable of the side-effects of individual control of various unrelated perceptions. Stigmergic effects, such as the effects of ruts on a muddy track on the ability of later wheeled vehicles to follow an arbitrarily chosen path, are of this common side-effect kind.

A prime example of collective side-effect influences on a common variable is climate change, caused by the fact that all control requires the deployment of energy sourced from somewhere, and seldom is the energy a component of the controlled perception. Nobody, I presume, actually is controlling for the Earth to become progressively warmer on a time-scale of decades, but the collective side-effect of control is that will happen unless inhibited by collective control.

The energy required for all control is ultimately dissipated as heat, but is sourced from some concentrated source. Currently, that source is often fossilized solar energy collected over millions of years by plants, but where the energy comes from is irrelevant to the control of a perception that needs it, and the fact that using the energy from fossilized solar radiation produces carbon dioxide that increases the temperature of the Earth is a collective side-effect, but not a side-effect of collective control.

Collective side-effects are important to study, but they are not relevant to this Chapter, which is about the restricted use of the term to refer to collective control of a single environmental variable. We will have things to say about collective side-effects a few times as we discuss social phenomena in the last few Chapters, especially in the Chapter on “Ownership and the Commons”.

III.1.1 Collective Control: Basic Concepts

The concept of “Collective Control” was introduced to PCT by McClelland (1993, 2004, 2006, 2014, chapter in LCS IV). McClelland studied the interaction of controllers that act to bring their perceptions of the same environmental variable to their different individual reference values. If those reference values differ, the situation seen by the Analyst is a classic conflict. The individual controllers do not perceive conflict, since their perceptions are only of the common CEV.

What I call a “classic conflict” is the kind McClelland demonstrated at the annual meeting of the Control Systems Group in 1993. In this kind of conflict, two separate controllers act on the same environmental variable but have difference reference values for their perceptions of its value. McClelland

demonstrated that despite the conflict that prevented either controller from bringing its perception to its reference level, an Experimenter/Observer who independently applied force to move the environmental both controllers were trying to control would see it as being controlled by a virtual controller with a gain that was the sum of the two gains and a reference value between the two individual reference values in proportion to their individual gains.

If, as was the case in McClelland's demonstration, the two controllers had output functions that incorporated integrators, the conflict would escalate indefinitely until one of them reached the maximum available output force, in which case the other would control the variable as though the weaker one was not there. Only during the escalating conflict did the virtual controller effect appear. This kind of escalating conflict can have dramatic consequences, as we discuss in Section IV.7.5, entitled "The Madness of Crowds and the March of Folly".

We call a virtual controller that appears in the interactions among two or more simple controllers a "Giant Virtual Controller" (GVC) that controls a "virtual perception" to a "virtual reference value", because if the Experimenter/Observer can use only the variable disturbance part of the Test for the Controlled Variable, the results are exactly the same as would be obtained from a real controller controlling its perception to that reference value. The Analyst, who can see both sides of the conflict, could know that the apparent control was the result of conflict. The individual controllers each would perceive a stubborn environmental variable (the CEV) that failed to move much despite increasingly strong action to move it.

The same applies if many controllers rather than just two control their perceptions of the same environmental variable or variables whose control necessarily influences a common variable. Since we usually take the Analyst's viewpoint, we give this environmental variable the name "Collective Corresponding Environmental Variable" or CCEV, to distinguish it from the CEVs of the individual perceptions. No matter how many individual controllers contribute to the GVC, each of them controls only its own perception of its own CEV.

When we are concerned only with a single dimension of variation, the CCEV is identical in effect to any the individual CEVs, so one might ask what is the point of giving it a different name. The answer is that very seldom, if ever, do any two individuals actually have identical perceptual functions. If one person is controlling a perception p=x+y, another looking at the same object from a slightly different angle might be controlling p=1.2x+0.8y. These are not the same, but if someone used the TCV by disturbing the object in different directions, that person might easily conclude that 1.1x+0.9y was a controlled perception, even though neither of the participants were actually controlling that (Figure III.1.1). Only the Analyst who could see what both were individually controlling would be able to detect that neither was controlling a perception of exactly 1.1x+0.9y.

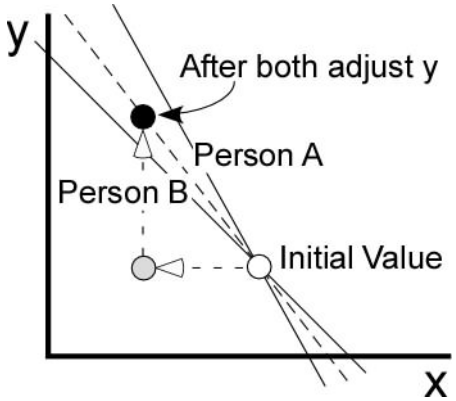


Figure III.1.1 If two controllers try to control CEVs that are similar functions of the same variables, the effect on the relationship between the two variables is exactly the same as it would be if a single controller were controlling an intermediate function of those variables. That intermediate function is the CCEV. In the Figure, a disturber changes the x value to the position of the grey dot and the two controllers both compensate by changing the y value. The CCEV moves to a position on the intermediate dotted line.

When there are more participants in the collective control and more dimensions of variation, the independent nature of the CCEV as distinct from any individual CEV becomes more evident, an important consideration when we come to topics such as the internal dynamics of political parties in Volume IV.

III.1.2 Stochastic Collective Control: A Gedanken Experiment

The interactions of people in a community are not continuous. You go to a shop and buy something, and then you leave, having perhaps interacted with a cashier. Later you may go to another shop and buy something else. There again you again interact with a cashier, who is a different person in a different environment. These interactions are one-shot for the persons involved, but as interactions between "a buyer" and "a cashier", they are repeat interactions between players of the Roles of customer and cashier. Both the buyers and the cashiers have learned how to perform the "paying for goods bought at a shop" protocol, regardless of who plays each of the Roles. Here we use the example only in order to introduce a form of collective control that we call "stochastic".

Imagine the following game as a *gedanken* experiment[1]. A number of players stand around a very large table that has a slippery surface. On the table lies an object like an ice-hockey puck, so let's call it "The Puck". Each player has access to a stock pile of objects like small flat pebbles that they can slide across the table to hit the Puck and nudge it a little (a "throw"). A player can get only one "pebble" from a stockpile at a time, so it takes a little time after each throw before they can get another pebble to throw. There is some device that automatically removes a thrown pebble from the table and returns it to the stockpile after it has hit or passed by the Puck, so the table is always clear of stray pebbles.

Phase 1 of the gedanken experiment — a common reference value. All the players belong to one team. On the table is marked a target location, and the team's objective is to get the Puck onto the target as quickly as possible. Figure III.1.2 suggests the effect of one pebble "throw" by the highlighted player.

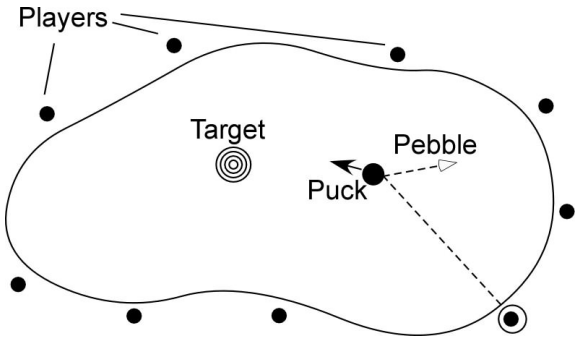


Figure III.1.2 The black dots represent players around the table. One of them has thrown a pebble, which bounced off the Puck, moving it a little away and to the left from the thrower.

1. The discussion of this game is largely quoted from a message I sent to CSGnet on 2011.12.20.

The team collectively controls the location of the Puck by hitting it with pebbles thrown from their different directions. Clearly, if they are to get the Puck to the target as fast as possible, the players for whom the target-puck-player angle is less than 90 degrees should not throw their pebbles. For the purposes of the game, we assume that a player is quite likely to hit the Puck, but cannot hit it on a chosen part of its circumference. This implies that individual players cannot direct the Puck accurately. Instead, when hit, the Puck moves in a direction that has a component away from the thrower plus a random sideways component opposite to that of the pebble's rebound that averages out to zero in the long run. The hit in Figure III.1.2 caused the Puck to move away from and slightly to the left of the thrower.

Consider the combined effect of three pebbles, one thrown by each of the three players on the right side of the table in the Figure. Roughly speaking, the most probable direction of the Puck if all three threw more or less together is the average of their three directions, but it could be anywhere in a wide arc. If there were more players, the distribution of directions would be more peaked. The total "force" (hits per second) in the most probable direction is a bit less than the sum of their individual hit rates (actually the sum of their hit rates times the negative of the cosine of the angle subtended by the person, the Puck, and the average direction). Figure III.1.3 suggests the probability distributions of the effects of their single pebbles and of the combination.

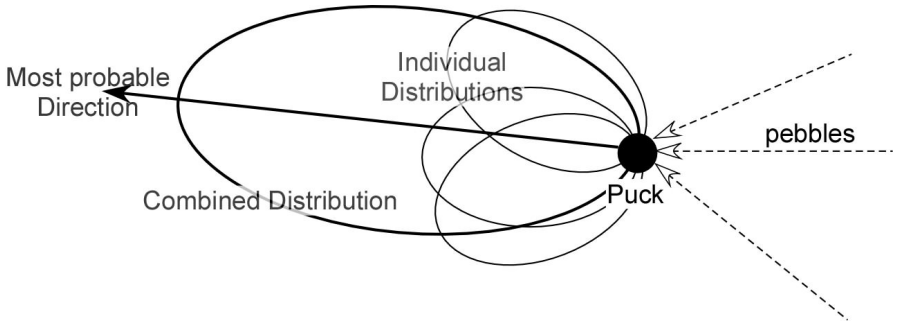


Figure III.1.3 The distribution of Puck move directions is more sharply defined by hits from several players than by hits from any one player.

Every time a pebble is thrown, the Puck moves a little in a new direction, but on average it will move toward the target if the correct team members do the throwing. Figure III.1.4 shows a possible track of the Puck toward the target.

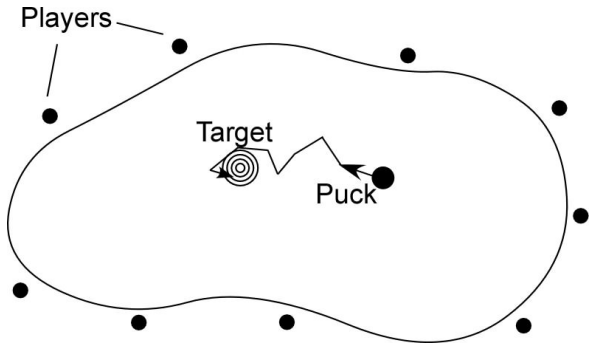


Figure III.1.4 A possible track of the Puck as it is hit always by those players whose throws would not be likely to move it away from the target.

If there were a lot of players packed tightly around the table and throwing rapidly, the Puck's track would be much more direct, deviating only slightly from a direct path toward the target. The effect, to an

observer who could not see the individual pebbles, would look as though the Puck was being slid smoothly over the table by an invisible hand, in the same way that we see smooth movement in a movie though we know it consists of discrete images spaced in time. Whereas individual players cannot direct the Puck accurately in a specified direction, the collective can, if there are enough team members.

When there are a lot of players, each hit has a proportionately smaller effect on the Puck. The game would be pointless if one hit moved the Puck a long way across the table, because if it did, then the multiple hits by a lot of players might send it right off the table beyond the target after just one throw each. So we must imagine two things, (a) that one hit moves the Puck only slightly, and (b) a player is less likely to throw if the Puck is near the target, so that the team avoids the Puck overshooting and oscillating erratically back and forth around the target location. The net effect is that the nearer the Puck is to the target, the smaller the apparent force pushing it there, just as is the case in a canonical control loop, in which the contribution to the output is proportional to the error value.

Phase 2 of the gedanken experiment — variation among individual reference values. In Phase 2 of the experiment, we remove the marking for the target. Instead, at the start of a trial, a game-manager points loosely to a spot and tells the players that where she points is the target location. The players therefore all agree in general where the target is, but unknown to any of them, their reference locations all differ slightly. So long as the Puck is far from the target, the situation is the same as in Phase 1, but when the Puck is in the general area of the manager's target location, some players will think it is to one side of the target while others think it is to the other side. Pebbles will hit the Puck from all directions, but more frequently so as to move it toward the average of the individual players' reference locations. Figure III.1.5 shows the difference between these two conditions.

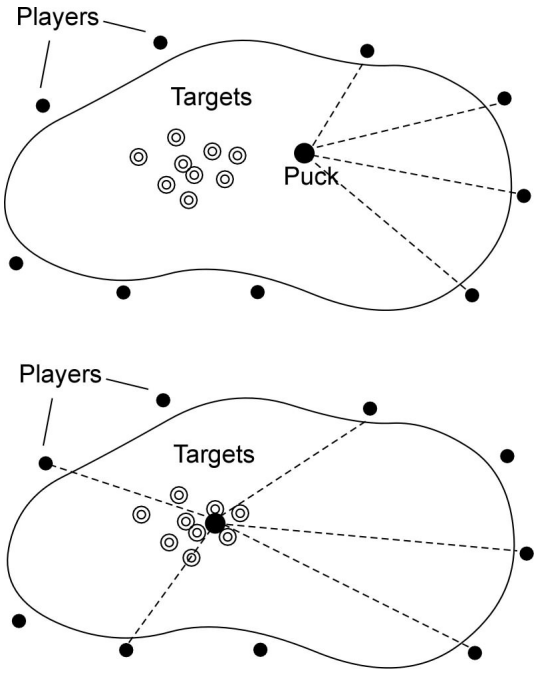


Figure III.1.5 When the Puck is far from the average of the reference locations of the individual players, it is hit mainly from one side, but when it is in the area of the individual reference values, it gets hit from all sides, albeit infrequently.

The Puck will move on average toward the average of the individual reference locations, but will continue to jitter around that point even when it is exactly there, because of hits that come more

frequently from the players for whom the Puck is relatively far from their reference locations. The team controls the Puck location as before, but with a virtual reference value that might not be the reference value for any member of the team. We might call the virtual reference value a Platonic Ideal for the target location.

Phase 2a of the gedanken experiment — freely chosen individual reference values. The only difference between Phase 2 and Phase 2a is that in Phase 2a no game manager provides a higher-level objective for where the Puck should be. The players individually choose a reference location. The analysis, however, is identical. An external observer who does not see the players or the pebbles would simply observe the Puck moving always toward a location that is the centroid of the individual reference locations of the various players. The wider the scatter of individual reference locations, the more the Puck will jitter around its virtual reference location.

Phase 3 of the gedanken experiment — teams in conflict. This time, the game manager tells some of the players one target location and the rest a different target location. The individual players do not know each other's instructions, but the manager's instructions have divided the players into two teams or groups. In Figure III.1.6, group 1 is marked by grey dots around the table. Their reference values for the target location are the right-hand set of reference locations, filled grey. The black dot players with black dot target reference values represent group 2.

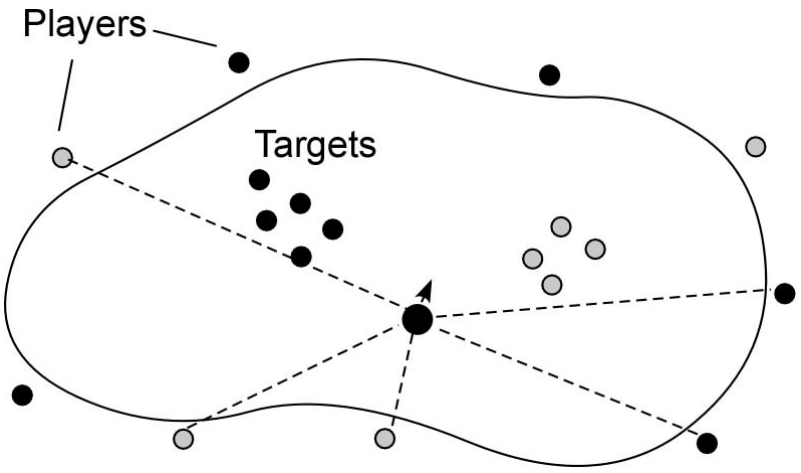


Figure III.1.6 The individual reference values are clustered around two distinct centres rather than one, as though there were two different teams in conflict about where the Puck should be, but as before the Puck moves to a place that is the overall average location.

The puck is being hit with pebbles from players who try to move it toward their particular target reference location, which means that in the diagrammed position of Figure III.1.6 most of the hits from both groups will move the pebble "northward", but in the east-west direction it will be hit from the right by pebbles from the "black" players and from the left by "grey" players. It will tend to move in whichever direction it receives most hits. If the Puck nears one group target area, their contribution to the apparent force on the Puck will diminish and the contribution of the other group will increase, so that the Puck will jitter around some point between the average targets of the two groups.

The situation is exactly the same as in Phase 2. Only the game manager knows that there are two separate clusters of target reference locations. An uninformed observer would see the Puck being controlled to go to a position between the two cluster centroids.

The distinction between Phase 3 and Phase 2 is only in the bimodal distribution of the individual reference locations for the target. Instead of all being randomly clustered around one Platonic ideal virtual reference level, they cluster around two. The result is that the Puck will tend toward a location that is the average of all the individual reference locations, and that fact remains unchanged from Phase 2. The effect on the Puck is still as if a hand were controlling a perception of the Puck location with a reference location near the centroid of all the individual reference locations. McClelland's 1993 demonstration involved only two controllers with different reference values, but this Phase 3 of the *gedanken* experiment shows that the same result would be obtained if each of the individual controllers in his demo had been Giant Virtual Controllers.

III.1.3 Stochastic Collective Control in Action

For a moment, we will move from the two-dimensional collective control of the *gedanken* experiment, and restrict our consideration to stochastic control of a single variable, analogous to a little cart on a rail, moved by throwing stones from positions on the rail at one side or the other of the cart. The stones may be big or small, and successive stones may be thrown from either side at random. In such a situation, the cart's location is not controlled, but the cart moves along the rail from side to side erratically. Even if the stones are all thrown with equal weight, the cart is highly unlikely to stay where it started. Indeed, statistical theory says that if stones are thrown from one side or the other at random, with the throwing side chosen by a coin toss, after N throws the cart will be somewhere on a distribution centred on the original location, but with an expected distance (if we did the experiment many times) of $\sqrt{N}$ times the distance the cart moves for a single throw.

In much of the last half of this book we will be dealing with collective control that occurs when many people interact. Interactions between particular two people playing their separate Roles happen and then are finished. You, playing the Role of customer, interact with a person playing the Role of cashier to pay for a purchase, and then you leave the shop. The interaction pair do and say various things because they are controlling some perceptions, and eventually either the controlled perceptions are near their reference values or the participants decide to give up (Chapter II.12.14 considers how this happens in a protocol). Each interaction can be considered analogous to the throw of one pebble at the cart.

Maybe these same two people as persons will meet often, as they would if they were close relatives or co-workers, but maybe they never met before and never will again. In either case, they must have some way of determining what each other wants, or the interaction will satisfy neither. The Roles in which they meet determine the protocols each expects the other to use, and if the persons have developed in the same culture, the protocol each expects the other to use will be the same, because the Roles conform to each other, as do Dentist and Patient or Customer and Cashier.

A suitable "way of determining" could be a commonly used gesture such as a smile or pointing at objects, or it might include a large set of culturally common actions and a common language. Those common actions and language either work for the participants in controlling their perceptions or they don't. If they don't then the "pebble" will be "thrown" in the sense that reorganization may alter the way the participants later use their cultural and linguistic control systems when interacting with one another. The roles themselves may change their collectively controlled properties. Ways of interacting will tend to converge because of repeated interactions between the same roles, but not necessarily the same partners, as those roles evolve.

Within a community in which everyone interacts with everyone else to some degree, this is likely to mean that the interaction styles of the whole community converge, though the point of convergence may well be subject to a modified "Brownian motion" drift for several reasons. Firstly, the individual effects of

reorganization are variable, secondly the rates of interaction between different pairs of people vary greatly, and thirdly the contexts of different interactions affect the progress of the interaction, and those contexts may be highly variable. Cultural and linguistic commonalities thus are developed and maintained by stochastic, rather than deterministic collective control.

III.1.4 Are Our Own Perceptions Virtual?

Phase 4 of the gedanken experiment — Testing for the Controlled Variable. We return to consideration of the gedanken experiment with which we began this Chapter. In Phase 1, a team uses stochastic collective control to move the Puck to a target, which is the reference value of their perceived location of the Puck, the same for all of them. In Phase 2, every player had a different reference location for the perceived target, but all the reference locations were clustered around an "ideal" target. In Phase 2a, the players' reference locations were scattered around the playing surface. By Phase 3, the individuals not only had different reference locations for the Puck, but their reference locations were scattered around two different cluster centres. Nevertheless, the location of the Puck in all the phases appeared to be controlled to a single reference location, even though in Phase 3 that apparent reference location was far from the reference location of any of the players.

In this new Phase 4 the situation for the players is exactly as in Phase 3, but we now introduce a privileged player, who we can call the "Disturber" or "Dee". Dee can move the Puck freely where and when she pleases. The players cannot see Dee, though she can see them and the pebbles they throw. The players see only an invisible force moving the Puck from one place on the table to another. Dee wants to determine whether the Puck location is being controlled, and if so, to what reference value. So from time to time Dee slides the Puck to a random place and watches what happens. When she moves the Puck, the thrown pebbles will move it back toward the virtual reference location. For every player, the Puck is not where the player wants it to be, but if an individual's reference location is beyond the Puck, the individual will throw.

From Dee's point of view, the fact that the Puck keeps moving back to the same place no matter where Dee moves it is not enough to establish that its location is being controlled. For all she knows, the table might be bowl-shaped, and the Puck might just be sliding back down to the low point. The pebbles might be having no effect on it at all. So Dee needs to do more. She must either prevent the players from seeing the Puck or prevent their pebbles from hitting it. She tries both.

Let us say she hides away the pebble stock pile, so the players have no pebbles to throw. Now when she moves the Puck, it stays where she puts it. Dee now knows that the Puck does not simply slide back down a slope after she moves it, and she replaces the pebble stockpile. The pebbles are essential if it is to move back.

Next she tries putting a dry-ice fog over the table so that the players cannot see the Puck. Once again, after she moves it, it stays put, perhaps jiggling a little when it is hit by an occasional pebble from a random direction, but not moving preferentially toward its former location.

Dee has completed a version of the Test for the Controlled Variable (TCV), and her results might lead her to theorize that the Puck location is being controlled by an entity (who Dee calls "Con") for whom the players are simply agents. The players, in her theory, continually observe the Puck location, report their observations to Con, and throw pebbles when Con instructs them to do so. According to Dee, Con controls his perception of the Puck's location, using the players as the equivalents of his eyes and muscles.

Not having considered the idea that the players are acting entirely on their own, Dee has come to the defensible conclusion that "Con" exists and has an internal perception of the Puck location that he

controls by having pebbles shot at the puck from different directions. But ***we*** know that Con does not exist and does not need to exist if Dee is to observe what she observed. Only the players exist, controlling their individual perceptions of the Puck location according to their individual reference locations for it.

How do we know that within any one player there exists a perception of the Puck location? We don't. We are in the same predicament in that respect as Dee is with respect to Con's perception and reference value, which we know don't exist because we know that Con does not exist. Without examining the inside of the individual, we cannot know whether any perception in anyone else is virtual or can be localized to a single variable value within the person's perceiving system. What we do know is what Dee knows about the game situation — that what we can observe is what we would observe if a perception we are apparently controlling actually does exist as a unitary value somewhere in the brain.

A quote from a Bill Powers message to CSGnet [Bill Powers (961224.1145 MST)] is relevant (bolded emphasis mine):

> *"Remember that **as far as the observer is concerned**, what is controlled is ONLY the CV. The idea that this CV is represented by a perceptual signal inside the other system is theoretical. We can observe CV, but not p. When we apply a disturbance, we apply it to CV, not to p. The action that opposes the effect of the disturbance acts on CV, not p. The Test does not involve p at all. It involves only observables -- i.e., the observer's perceptions. The observations have priority; the model comes second, and its only reason for existence is to explain the observations."*

Now think about the concept of a "Neural Current" that Powers introduced as a useful simplification of the firings of myriads of neurons. It is a fictitious quantity that is the sum of many one-shot events — nerve firings, not pebble throws. The idea of there being a "perceptual signal" to be controlled depends on the notion of the neural current. Indeed, a perceptual signal in PCT is *defined* as the value of a neural current. The output signal in PCT is the value of another neural current, closely analogous to the summed force on the Puck of a barrage of pebbles thrown by different players. To perhaps belabour the point, the neural current does not exist as such in a brain. It is a concept in the mind of a theorist, and perceptions that are the values of this theoretical quantity do not exist as such in the brain. They are as virtual as is the perception controlled by Dee's non-existent "Con". They are no less real for that.

Consider the muscular output part of a control loop in an ordinary vertebrate. The tension in a muscle is related to the rates of nerve firings sent to its many fibres, and the angle of a joint is set by the balance between the firings on the fibres of the opposed muscles. Phase 3 of the gedanken experiment looks much the same as setting the joint angle, one nerve firing corresponding to one thrown pebble. The muscular opposition corresponds to one group of pebble throwers trying to move the puck to somewhere within one cluster of reference locations while the other group tries to move it to the other cluster, the result being an apparently controlled location of the Puck (analogous to the joint angle) between the two clusters.

If there had been a "Con" directing all the players when to throw, Con could have moved the Puck in a controlled manner by telling one group to throw more slowly and the other to speed up. Likewise we move our joints in a controlled manner by relaxing one set of muscles (with fewer nerve firings) and tensing an opposed set. The tensegrity structure of control works, so as to speak, hand in hand with the physical tensegrity structure of the body.

This kind of thinking was behind the comment in Section I.7.4 "*Suppose now that the imagined world is not completely dissociated by switches from the real world. Suppose real world perceptual values contribute to an imagined world and output values derived from the imagined world contribute to reference values in the real world*." The same collective control might be true of perceptions themselves.

Some perceptual input fibres might receive more synaptic input from imagination, combining with contributions from the senses, and similarly for contributions to lower-level reference inputs, allowing perceptual functions to be connected in a fluidly varying fashion to inputs from the senses and from imagination, depending on how consistent or strong was the sensory component.

Here we refer back to Powers (1973a/2005) and continue the quotation cited in Section I.4.1. Right at the beginning of B:CP, in the "Premises", Powers writes:

> *As the basic measure of nervous-system activity, therefore, I choose to use* neural current*, defined as* the number of impulses passing through a cross-section of all parallel redundant fibers in a given bundle per unit time*. ... statistical variations will not be important at any level of neural current in proportion to the whole normal range of operation.*

Here Powers uses "redundant" to indicate "passing identical information", rather than in its technical sense of passing information in a way that could at least partially be reconstituted from that passed by the other fibres if a particular fibre failed, and that each fibre would contribute to restoration of the information passed by any other failing fibre. Indeed, even though many fibres may pass similar information, it is highly unlikely that any two have the same set of input and output connections and synaptic weights. Quite probably no two nerve fibres always fire at the same time or at exactly the same rate.

The consequence is that we have to consider a controlled perception within an individual as not being carried by the firings of any precisely defined set of neurons, and the perceptual function that produces this signal as never being precisely located anywhere in the nervous system. The situation is conceptually that of collective control, perceptions controlled by an individual being as "virtual" as are those of Giant Virtual Controllers. It is therefore not necessary to PCT that the perception the TCV identifies as being controlled exist anywhere within the individual, it being equally possible that many different systems that specify similar perceptions combine to create a virtual perception that is identified by the TCV.

Does the non-localizable property of a perception cause a problem for the Theory of Perceptual Control? Not at all. What matters for the organism is the effects of environmental disturbances and internal influences on the intrinsic variables. If the effects are the same as though a singular perception or hierarchy of perceptions is controlled, it is totally immaterial whether each controlled perception is located in a single (bundle of) nerve fibre(s) or distributed over the whole of the brain. Distribution over slightly differing signals in hundreds of fibres simply renders the perceptions and their control less vulnerable to microscopic physical damage to the brain, though of course macroscopic damage does result in observable symptoms.

Another benefit of a distributed representation of the controlled perceptions is that a virtual perceptual function can modify its properties quasi-continuously rather than in discrete jumps as synaptic weights change, and as synapses are born and die. The conscious perceiver may well not notice such change happening and just go on happily controlling what seems to be the same perception, perhaps increasingly accurately prescribed or with an increasingly complex contextual structure.

Having come full circle from an analysis of the collective control by people in a culture, back to the control of perceptions by individual organisms, we may now treat the analogy between individual control and social control as less of a metaphor and more as subject to similar mathematical and structural influences.

In particular, we may expect that the Hebbian and anti-Hebbian processes hypothesized for neural systems will play out in similar fashion in the social sphere, competition and collaboration both being

important. But, you may say, the Hebbian processes apply to the changing strength of individual synapses. If the neuron to which the synapse provides input fires just after the neuron on the other side of the synapse has fired, then that synapse is strengthened. Its contribution to the probability that its neuron will soon fire the next time its incoming partner neuron fires is increased. The opposite is true if the incoming neuron fires shortly after the synapse's neuron fires.

Incoming neuron firings are sources of information about the pattern of events in the world to which the neuron of interest is sensitive. Consider how that might relate to human communication. If you hear from a source some information about something in which you are interested, that combines with information from other sources to form a pattern that induces you to do something such as pass on the information to your friends, that source may seem fractionally more reliable than before, but if you hear it after you have acted, the source might have got the information indirectly from you, and even if not, they are late telling you, so you may perceive them as fractionally less reliable. If the same timing pattern happens time and time again, you may come to rely heavily on what the earlier friend tells you, and to ignore what the one says who habitually tells you late what you already have heard from elsewhere.

Companies selling similar products to a similar clientele may either combine to induce the public to buy more of the product, to the benefit of both companies, or inhibit each others' progress, perhaps to the extent that one dies. Technologies that, to the user, seem to perform the same job, such as VHS and Betamax in the early days of videotape recording, compete similarly, only one (VHS) surviving. The mechanisms may not be the same, but the lateral inhibition has the same effect, of producing flip-flop effects in which one of a category becomes strong while others diminish in influence or die.

We see also that, just as a measurement can never provide an exact value for the thing measured, so also the Test for the Controlled Variable can never tell an outside observer exactly what perception is being controlled, for the answer is likely to be that there isn't "a" controlled perception, but a bundle of many similar ones in parallel within either the individual brain or the social collective. The Test is no less important for that, because it is able to discriminate clearly among distinct alternative possibilities that differ by more than its inherent range of uncertainty, and when people interact through protocols, they often unknowingly use The Test to determine what each other perceives and with what reference values.

We live because things "out there" usually change as they would if our perceptions were veridical when we control them, even though the perceptions we control are themselves only virtual. We are all Stochastic Giant Virtual Controllers. When we come to deal seriously with social phenomena, we will be more interested in Stochastic Giant Virtual Controllers that consist of different individuals interacting through their common environment, like the players in the game. Stochastic collective control in our environment allows us to create artifactual entities such as ways of behaving with respect to each other that are stable, reliable, ways of getting what we want — atenfels that are often intangible. They are among the stabilities that require work for their maintenance that are described by McClelland in the extended quote in the introduction to Chapter II.4.

III.1.5 The Giant Virtual Controller and the Platonic Ideal

As we saw in the gedanken experiment, when several people try to move the same thing, but have different reference values for their perceptions of its location, no one person can move it very much, unless that person has many times the power available to any single one of the others. That "stability in numbers" is at the heart of the concept of collective control.

If many different highly skilled artists are each asked to draw a "circle", none of their productions will be geometric circles, though to the untrained eye they may all look as though they are. If the untrained observer sees enough of these productions, the concept of the geometric circle is likely to become a

reference, a Platonic ideal, for a perception that might possibly be controlled, whether or not a formal definition of a "circle" is available.

The reference "Platonic" ideal circle compared to the artists' renditions is analogous to the CCEV as compared to the individual CEVs. The CCEV is whatever function of environmental variables most closely resembles all of the CEVs of the collective controllers. If one of the individual controllers changes the reference value for its perception of its CEV, that change will be reflected in a smaller change of the CCEV. In what follows, we will often use shorthand language, and say that the CCEV is controlled by a GVC (Giant Virtual Controller), even though the CCEV actually corresponds to a controlled virtual perception that is some average of slightly different perceptions controlled by the various actors.

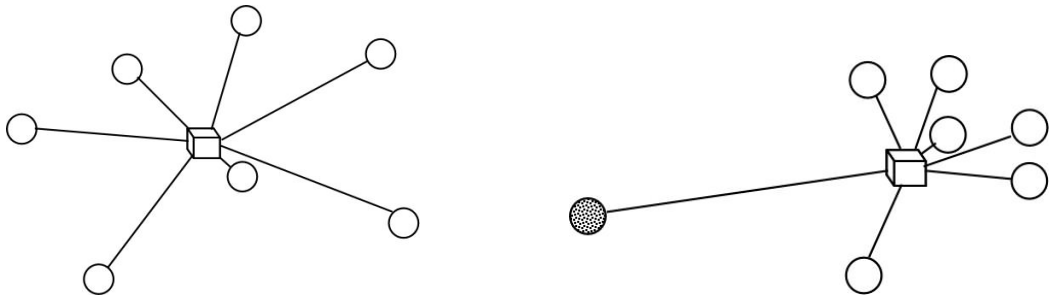


Figure III.1.7 (a, Left) When several controllers try to move their CCEV (the location of the box) to their individual preferred locations, the CCEV winds up somewhere in the middle, and remains stable. (b, Right) If a stranger tries to move the object to a different location when it is near the crowd's preferred location, the stranger will not move it far.

Figure III.1.7 shows two characteristic configurations in which a group of people control similar perceptions and thus create a CCEV, which is shown here as a box being dragged in a two-dimensional space. In other words, the members of the group are controlling two different features at once, as are the players in the *gedanken* experiment. The features could be as simple as the X-Y placement of a glass on a table or the pitch and intensity of a vowel, or as complex as the honesty and ability of a prospective new employee. The concept is most easily depicted in two dimensions, but can be pursued in as many dimensions as are appropriate to the situation, such as the three components of the "syncons" used by Len and Sophie's family (Chapter 1), or the many dimensions of their "synx" trajectories[2] (Figure II.12.10 to Figure II.12.18).

Imagine that each line in Figure III.1.7 represents a rubber band being pulled by people, all of whom want to perceive the box to be on their own circle. The more stretched the band, the stronger the pulling force, just as the Puck in the gedanken experiment is the object of a pebble throw more frequently by a particular player the further it is from that player's reference location. Nobody gets the box where they want it, unless by chance it happens to be at their reference location because of the pulls from all of the others.

In Figure III.1.8a which repeats Figure III.1.7a with tolerance zones added, the people are all pulling in different directions, and the box is in the middle among their various reference locations, within the tolerance zone of only one of them. In Figure III.1.8b, the box is in a cluster of people who more or less agree about where it should be because they have a larger tolerance zone than the people do in Figure III.1.8a, and they all can tolerate that the box location is only marginally acceptable in order to come to a compromise location for it.

2. . Syncons and the synx are artificial constructs that were defined in Chapter xII.10.

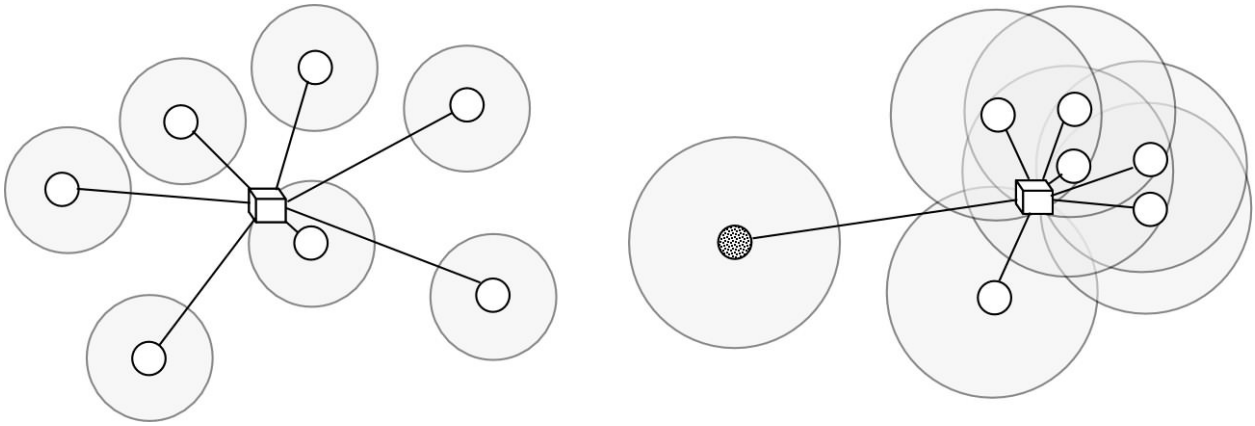


Figure III.1.8 The same situation as in Figure III.1.7, but now each controller tolerates a deviation of the box from its reference location so long as it perceives the box remaining within a tolerance zone suggested by the grey disk. In the left panel, only one of the controllers is satisfied with the current location; the others continue to try to move the box toward their own reference values for it. In the right panel, all the older controllers are satisfied, though many of them only marginally so. Only for the stranger is the box sufficiently far from its reference value to cause a non-zero error signal to the controller's output function. However, if the stranger does move the box appreciably, some or all of the others will act, if only gently at first, to oppose the move.

The people in Figure III.1.8b have a Platonic Ideal collectively created, perhaps an agreed political party policy, but an outsider now is trying to move the box to a very different place. The original cluster of people opposes the disturbance introduced by the outsider, but since the outsider is also a controller, the box is likely to move, if only very slightly, to a new stable position. The original cluster holds the box very near where they had held it before the outsider arrived, exhibiting the "stability in numbers" inherent in collective control, even though none of the participants wants the box to be exactly where it is.

Of course, control is not the same as stretching a rubber band, especially in its dynamics. Dynamically, if the controllers are linear and use the integrating output function so often used in PCT simulations, opposing controllers escalate their output without limit. Actual controllers are not linear, and may not escalate their output, but even if they do there is a limit on how much output they can produce. When they reach their limit, they have no further influence on how the CCEV changes when disturbed (McClelland, 1993, 1997). Different kinds of nonlinearity and different time-dependences of the output functions provide results that are different in detail, but similar in their broad effect, which is that they arrive at a stable distribution of output and a stable value for their common CCEV (the location of the box in either panel of Figure III.1.8).

One must be careful when working with the Giant Virtual Controller, because its characteristics might not be quite the same as those of the individual controllers that are members of the collective. For example, if we look at Figure III.1.8, its absolute tolerance zone exists only where the absolute tolerance zones of the individual controllers all overlap. In the left panel, the Giant Virtual Controller has no tolerance zone, whereas in the right panel it does if we ignore the stranger, though only a much smaller one than that of any of its member controllers.

On the other hand, the error function for a virtual controller with a tolerance zone is softer than that of any of its members, since if the CCEV moves only slightly out of its tolerance zone, only one or two of the members act to bring it back, and the GVC acts with only a low equivalent gain. The effective error

function of the GVC is shown (scaled) in Figure III.1.9 for a case in which each of the member controllers has a sharp error function like that shown in the inset and the CCEV is near the edge of some member tolerance zones but near the middle of others. If the individual error functions have a soft break from zero (as they will do because the neural current is itself a virtual signal), the virtual controller's error function is even softer.

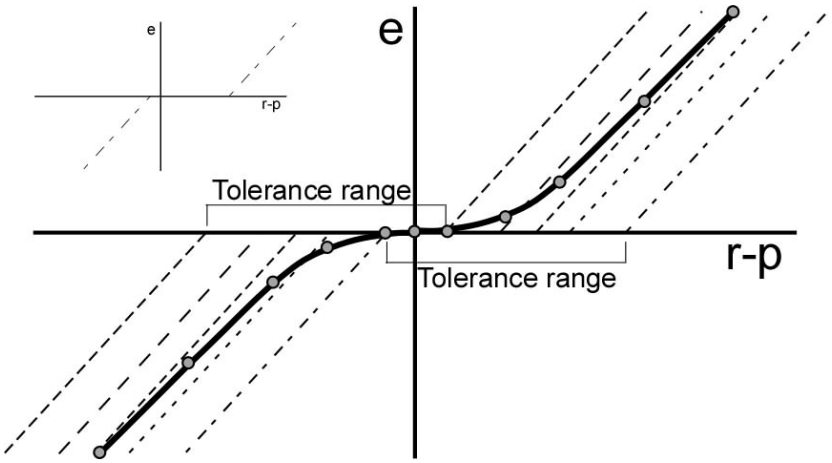


Figure III.1.9 A virtual error function (heavy solid curve) for a case in which the individual members of the collective have the same sharply defined error functions with a tolerance zone (light variously dashed lines), but different reference values. A representative example (the rightmost in the main figure) is shown in the inset. The effective error is the average of the individual errors, and the effective output is the sum of the outputs of the individual members.

Though correct, Figure III.1.9 might be misleading in one respect. It shows the error function of the "Giant Virtual Controller" correctly as an average of the contributing individual error functions, but the actual output corresponding to that error is the sum of the contributing gains, not their average. Although the virtual error function may be "soft", the force with which the collective acts on the CCEV is ordinarily stronger than that of any individual. We talk about individuals who are "authorized" to act on behalf of some GVC in much of the later part of this book. Such individuals are almost as strong as the collective that they represent. One of the reasons for elections in a democracy is to select authorized individuals to represent the collective.

The effect is that, although some of the individual controllers may act strongly to correct a large error in their own perceptions, nevertheless if the CCEV remains within the tolerance zones of the majority of the members of the collective, the Giant Virtual Controller will have relatively low gain.

The "mavericks" or "extremists" may take strong action[3], but usually their acts will not much influence the things they try to change. There are exceptions, mavericks who move the CCEV outside the tolerance zone of much of the collective while staying within that of many of the collective members. If the CCEV moves outside the majority of the tolerance zones, however, the virtual loop gain becomes very high unless the collective fragments into distinct groups (for example, the different Protestant religions that have proliferated since, and slightly before, the Reformation).

3. . Such "mavericks" are often called "terrorists" by members of the collective they oppose, whether or not they use violent means to advance their cause.

III.1.6 Stochastic Collective Control and Reorganization

Phase V of the gedanken experiment — collectively controlled reference values. We return to the gedanken experiment with a slight change in the structure. Rather than there being a single target and many players arranged around the table with pebbles to throw at the Puck, there is one player who we call Norman, and many others who arrive at the table one at a time. We will call them teachers. Each teacher has a personal preferred location for the target which may differ slightly from that of other teachers who come to the table. Norman has the only pebbles in the game, and his job is to get the Puck to a place on the table where every following teacher will tell him that it is close enough to their idea of the target location to satisfy them.

When a teacher comes to the table, Norman may throw a pebble. If he does, the teacher tells him whether the throw brought the Puck closer to that teacher's idea of the target location, as well as whether it arrived at a place within the tolerance zone of that teacher. If the previous teacher had told him that the Puck arrived at a place that was satisfactory, Norman does not throw, and the new teacher simply tells him whether the Puck is in a close enough to his or her ideal target location.

If he does throw and the teacher tells him it is now closer, Norman stands still to await the next teacher. But if the teacher tells him it is now further away, Norman moves to a different place around the table, which he chooses at random. Eventually, most or all of the teachers will tell Norman that the Puck is in a satisfactory place, and Norman will be throwing very few pebbles. Only teachers with very narrow tolerance zones or very deviant reference values will tell him that the Puck is still not close enough to their personal ideas of the target location.

This version of the experiment implements in two dimensions the e-coli process of reorganization, at least as we described it in connection with the HaH process in Chapter 9. The coordinates of the Puck represent weights in the output side of the perceptual control hierarchy. Those weights determine the reference values that will be used by lower level loops in controlling a particular perception. The teachers represent the success or failure of an attempt to control the higher-level perception by using the resulting reference value.

Translate this into Norman learning, say, to pronounce a word correctly. Success occurs when the listener (teacher in the experiment) understands what is said, failure when the listener understands something different or fails to understand at all. When most listeners understand correctly, Norman has learned to pronounce the word correctly enough to be able to control variables by using it with most people he encounters. The native speakers may perceive that Norman speaks with a non-standard accent, but what he says is intelligible. Norman has managed to produce an effective reference value for his pronunciation, a reference value that "conforms to a collective Norm", a linguistic "Platonic Ideal" for the word. Linguists call such Platonic Ideals "*langue*" and Norman's actual productions "*parole*".

The same applies at all levels of perception, whether in language or in any other domain of experience. The basic principle is the pair of mantras "*If at last it doesn't work, try something different*" and "*If it ain't broke, don't fix it*" which we have now used in talking about reorganization rather than about the ongoing process of control. The latter applies when Norman finds that most people understand him very well.

We are here repeating in a different form what we said about the learning of language in the process of interacting with others when we considered protocol form in Chapter II.9 and Chapter xII.12, and when we followed the story of Len, Rob, Sophie and their descendants in Chapter 1. "Langue" specifies idealized versions, "norms", of cultural variables that may then be defined in textbooks, dictionaries, and encyclopaedias, or incorporated into laws and rituals, written or unwritten.

III.1.7 A Short Taxonomy of Collective Control

If Collective Control occurs because of the competing efforts of two or more control units that differ in their reference values by more than their tolerance limits, they may find themselves in an escalating conflict in which their individual perceptions continually increase their error (and their output) while the CCEV remains stable. Individually, they have no control even though the CCEV gives the appearance of being the CEV of a tightly controlled perception. On the other hand, if their reference values are the same within tolerance limits, conflict does not occur, and all have their perceptions of their CEVs (which are very like the CCEV) well under control.

If the individual members of the collective by coincidence happened all to want to control a perception of much the same function of the environment, thus creating a CCEV, they usually would have different reference values for their controlled perceptions. Conflict would be almost inevitable. But much of the time, and especially in the case of language and culture, conflict over the "proper" way to talk or act seldom happens. The many individuals involved have come to agree on the "proper" reference values for the elements of language and culture. How can this be? How could they have developed the "norm" toward which Norman's reference value for the pronunciation of the word tended?

When we consider the development of protocols again in Chapter III.2, we will argue again that the correspondence of reference values is a consequence of reorganization that makes interactions "just work". But that is for later. Here we deal with an additional mechanism that is in play.

Imagine someone we will call "Gerry" who is controlling for being perceived as a member of a group. This perception will be in error if Gerry perceives that people act toward him differently than they act toward people whom Gerry perceives to be group members. "Acting toward" people in any consistent way implies that they participate in protocols that have some form known to all participants, but Gerry perceives that in certain contexts when she tries to use what she perceives as a protocol used between group members, the protocol does not serve to control the variable she is trying to control. She perceives that she is not being perceived as a member of the group, whereas her reference is to be perceived as a group member.

If the group is a formal one, the only way Gerry can join the group and be perceived as having done so is by participating in a ritual. Some authority declares and shows the group's collective that she henceforth belongs to the group. She may have paid the club initiation fee, passed an exam, been appointed as a magistrate, signed on as an employee, or walked on a stage and been handed a scroll of paper. If, on the other hand, the group is informal, such as a friendship set, she must learn to use the group protocols the way the group members do. If she does not, even though the group members may individually be friendly, she will be perceived as odd, and the group members will not act toward her as they do toward other group members. Gerry must use protocols "properly".

The PCT perceptual control hierarchy does not have any place for controlling output as such. Changing lower-level reference values is the only way a high-level perception influences its perceptual signal. Changing those reference values is the way the higher-level system *behaves*, in the sense of "Behaviour is the control of perception". In Gerry's case, her perception of belonging to the group has its error reduced when she begins to perform "correctly" a protocol that she had been wrongly performing. Eventually she performs it well enough that she perceives that the other group members accept it as appropriate. Her reference value (or profile) has been changed appropriately by the normal process of control, not by reorganization. "I want to be one of you, so I will try to behave as you do".

We thus arrive at a second form of collective control, which is distinguished from the first by the fact that the participants now actively control for having similar reference values for their perceptions of the CCEV that they are all influencing. The players in the gedanken experiment do not do this. To distinguish

the forms of collective control, we may call the first form “Conflictive Control” and this one “Collaborative Control”.

It is easy enough for a newcomer to converge to the usages of a pre-existing group, but when an ad-hoc group comes together to do something, it may be hard for them to come to an agreement on the appropriate reference value(s). Often, they may agree to accept a leader who will provide the reference value that will be accepted by the group in the same way as would be the case in Collaborative Control[4]. We may call this third case “Coordinated Control”.

We thus have at least three types of Collective Control in which all the members act on the same CCEV as a means of controlling their own perceptions.

1. Conflicted Control: The participants have independent reference values for perceptions whose CEVs are closely related to the CCEV. The CCEV remains as if it corresponds to a controlled perception, but the outputs of the individual controllers tend to increase as in any conflict. Several people push on a rock, all wanting it in a different place.
2. Collaborative Control: The participants control a higher level set of perceptions of belonging and being seen to belong to “the group”, bringing toward a common value their references for their perceptions of the CEVs that combine to form the CCEV, eliminating the conflict while maintaining strong control. Several people push on a rock trying to move it to a place on which they agree.
3. Coordinated Control: All members who are controlling for being perceived and perceiving themselves as belonging to the group accept reference values provided by an agreed leader. Several people push on a rock trying to get it to a place chosen by the leader.

In addition, there are at least three forms of Collective Control in which the participants act on different aspects of the environment in order to achieve a common higher-level purpose — a reference value for a higher-level CCEV — that all have in common, rather than all trying to influence the common CCEV in the same way. We will consider some of them in more detail later.

4. Guided Control: A plan, with or without a specific planner, determines who does what (I’ll hold the pole if you hammer it into the ground; I’ll get the supplies if you guys get the the tents put up.) The similarity should be clear between this form of collective control and a two-level hierarchy.
5. Giant Real Control Unit: Different people or groups of people use protocols in ways that mean that some play the roles of the different units of a control unit (Sensors, Perceptual Function, Reference Function, Comparator, Output function, Effectors), so that the whole social structure acts as a controller. This concept is elaborated in Chapter IV.1, Chapter IV.2, and Chapter IV.3, especially Section IV.2.1.
6. Hierarchy of Social Control Units: Same as 5, with different levels of controller interacting as in the Powers hierarchy for control units within an organism.

These six forms of collective control are not definitive, but apart from the first form, they all achieve the power of increased loop gain without the cost of conflict, except possibly during the process of selecting a leader or otherwise developing the collective control structure.

This avoidance of conflict in playing roles does not rule out “office politics”. Indeed, it may exacerbate such conflicts, as happens if two individuals both control a perception of seeing themselves

4. The perception of the identity of the leader is collectively controlled in the first sense, that of Phase 2a of the gedanken experiment, Conflictive Control.

playing a role that can be played by only one person at a time, such as “office manager” or “President of the United States”. Playing those roles does not inherently involve conflict with those playing the roles of “worker in the office” or “US citizen”, but it does inherently involve conflict with anyone else wanting to perform that specific role.

As is the case for the control systems within an individual, Giant Real Control Units such as the single one of Collective Control type 5 or the hierarchy of type 6 can conflict with other control systems, whether individual or collective. The individuals who control their perceptions in order to perform their roles in these Giant units are not ordinarily in conflict with each other, though they might be. Scarce resources may be allotted to one unit and made unavailable to another, for example. Within an individual, the “Method of Levels” (e.g. Carey, 2008; Mansell, Carey and Tai, 2011), has proved useful in cases of this kind of conflict. Might it not also be useful in cases of conflict within a type 6 Giant Real Control hierarchy such as a company?

By the end of Chapter xII.14, we will have two forms of collective influence on large-scale change, beyond simple collective control. In the first form, on which Chapter xII.14 concentrates, side effects catalyze other control processes by making control easier, more effective, or more efficient (or the opposite). Such side-effects are likely to be autocatalytic.

The second form occurs when many individuals controlling similar or even different perceptions produce similar side-effects that have a net side-effect that has an average influence far from zero on some variable unperceived by any of the controllers. The results are always unintended, and are more likely to be detrimental than beneficial to the individuals who cause them.

These are situations in which some side-effects of control by one individual are dissipated through the environment and have a much smaller detrimental effect on that individual’s own intrinsic variables than the beneficial effect of controlling the perception. The same trivial detrimental effect, however, affects many individuals in that environment. If they all controlled their perceptions in ways that had the same side-effects, the summed detrimental influence on any one of them might well outweigh the immediate benefits to their intrinsic variables of their controlling. The Tragedy of the Commons (Harding. 1968) is a generic statement of the problem, which we will consider in more detail in Chapter III.8.

A specific example globally is climate change as manifest in global warming, and perhaps more importantly, ocean acidification. An analytical scientist may deduce from theoretical principles that increasing CO_2 in the atmosphere would make the Earth hotter and the ocean more acidic, but nobody can perceive the global average temperature for themselves without specialized instruments and mathematical techniques, and neither can anyone directly perceive the changing acidity of the ocean. They are side effects of actions every person does in controlling multiple perceptions, from deciding whether or not to have a child, whether or not to drive an SUV as opposed to a small electric car, and so forth.

These may be the most dramatic and important consequence of collective influence through the combination of side-effect influences in the everyday world, but there are many instances at much smaller scales, connected only by the fact that, being side-effects, they are unrelated to what the actors are controlling by their actions that produce the effects. The actors who collectively produce them are unlikely individually to perceive them, except insofar as the effects ripple out through the environment, returning later as disturbances to perceptions that they do control.

III.1.8 Tensegrity of Collective Control

In Chapter I.8 and Section II.3.4, tensegrity was discussed as a property of sufficiently complex control structures, as well as of appropriately constructed physical systems of enough rods and wires. Can

we argue that collective control also may exhibit tensegrity-like properties under suitable circumstances? I think we can, and in fact we did by pointing out the relationship between the forms of collective control in which the members of the collective control different perceptions that contribute to a common goal (Forms 3 to 6 in the "Short Taxonomy"). Now we follow that thought to see where it leads.

The central property of a tensegrity system is that stresses applied at one place are distributed widely throughout it, to reduce the strain around any one point. The function of a "rod" in a physical tensegrity construction is to keep the wires in tension. An equivalent construct is essential if any different kind of system is to exhibit tensegrity. We discussed this in the context of an individual control hierarchy in Chapter I.8.

In in that Chapter, we used the example of a simple two-level control hierarchy, in which the "rod" is a structured perception at the upper level that supplies reference values for the lower level control units. Equivalently, the "rod" could be a physical relationship in the environment such as the requirement for "correct" placing of chairs around a formal or a restaurant dining table. In a two-level hierarchy the "wires" "pull" perceptions toward the reference values provided by the upper of the two levels. In a collective control system there is no apparent analogue of the levels, other than within the individual control hierarchies, so we must look elsewhere for our "rods". We already have "wires", the collectively controlled "pulling" of the CCEV to correspond to the virtual reference value of the virtual perception of the Giant Virtual Controller.

Referring to the "short taxonomy", one might anticipate tensegrity effects in conflictive control, in which disturbances to the CCEV are resisted by a single Giant Virtual Controller. There is a difference in the two reference levels, and so long as that difference continues, the "rod" maintains the tensions applied by the two antagonists' individual control actions. But this is not sufficient to produce tensegrity, any more than is a rubber band stretched between two ends of a stick. The control structure needs to be bigger and more varied.

Do we expect tensegrity effects due to collective control as opposed to those due to individual control in "Collaborative Collective Control"? No, we do not, since the only difference between this and Conflictive Collective Control is that the putative "rod" has been shrunk out of existence. There is even less suggestion of tensegrity here. Nevertheless, it is true that in Collaborative Collective Control if one member of the collective works less, the others must work harder to compensate, and vice-versa if one works harder. That is not true tensegrity, but the Collective still has the distributive character of a tensegrity structure. At first sight it may seem as though Collective control, apart from its mimicry of simple control, does not exhibit inherent tensegrity. But perhaps we should hold off on this judgement until we have examined Coordinated Collective Control.

The third class of Collective Control in the taxonomy is "Coordinated". At this point we lose the possibility of structure imposed from above. "*All members controlling for perceiving themselves and being perceived as belonging to the group accept reference values provided by an agreed leader*." We could add to this "*or by agreed rules of the Collective, such as a club,a society, or even a family*".The Coordinated Giant Virtual Controller has a higher second level, which I call the "Leader", that sets reference values for the different virtual perceptions that when controlled together result in some common goal being achieved, or at least attempted. The structure of the plan is not a controlled perception of any of the individually collectively controlled perceptions during its execution.

One might well say that the structure of the goal — the virtual reference perception — of the coordinated collective is in the head of the leader, and this would be true, but the implementation, the control of the related components, is in the individual Grand Virtual Controllers, which have a role parallel to that of the lower-level controllers in the two-level tensegrity structure of Figure 8.20, as suggested in Figure III.1.10. No one of these lower-level GVCs necessarily exhibits tensegrity by itself,

but the Coordinative Collective does. One important fact that might have been lost is that the members of the lower level control structures, which may be themselves distinct Giant Virtual Controllers all are collectively controlling for the same higher level purpose that provides the same or similar reference value to all, no matter what feature(s) the individual GVCs overtly control.

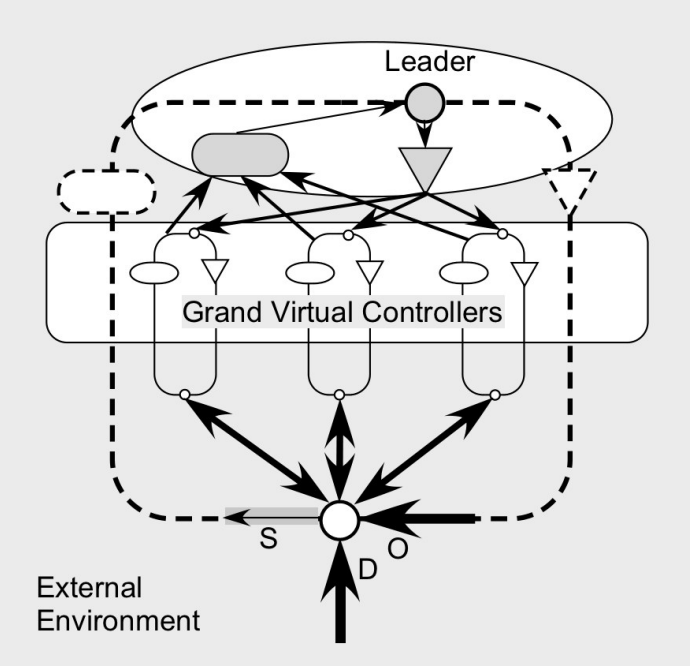


Figure III.1.10 A Leader has as reference a plan for what the supporters are expected to accomplish, which produces a structure analogous to that of Figure 10.6. The supporters are now control systems in different individuals or collectives, so communication of reference values downward and perceptual values upward is not by direct neural communication but through the environment, often by language if the players are human.

In Figure III.1.10, the links between the Leader and the supporting GVCs must pass through their common external environment, whereas in Figure 10.6, the reference levels are set directly by the output of the upper-level ECU, and the perceptual function of the upper-level ECU has as inputs the perceptual values of the lower. Such direct connections are not available when the control units of the lower-level are in different individuals. Nor need the supporting controllers be in single individuals, though they might be. They are shown as Giant Virtual Controllers in Figure III.1.10, implying that each combines the collective control of several individuals. For the tensegrity implications of the structure and of similar structures that might involve the supporting individuals or GVCs belonging to different groups, it makes no difference.

Either way, the reference levels must be communicated from the Leader through the environment, by language if the participants are human, but by other means if they are not. Similarly, the perceptions that signal the environmental states perceived at the lower level in Figure 10.6 are wired directly into the inputs of the upper perceptual function, but now they, too, must be communicated through the environment. The mechanism for this is the "protocol" (Chapter II.9, Chapter xII.12).

One function of a protocol is to reduce the probability that a communication will be misinterpreted, but the probability is never zero, and all the inter-level signal paths of Figure III.1.10 must be considered

to be noisy. The effect of noise in a channel is to reduce its information "channel capacity", and therefore to reduce the quality of control. In the tensegrity analogy, it slightly relaxes the tension in the "wires", possibly reducing the diffusion of stress through the structure. This issue, however, is counterbalanced if the lower-level is formed of Giant Virtual Controllers, which have higher gains than do the individual controllers that are members of the GVCs.

At this point, we must reconsider something from a few paragraphs ago: "*Do we expect tensegrity effects due to collective control as opposed to those due to individual control in "Collaborative Collective Control"? No, we do not...*". But maybe we should. After all, it is not the Leader that supplies the reference values used by the lower-level control loops. It is the plan hatched up by the Leader, and plans can be developed by people controlling collectively, a situation described above as "Guided Collective Control". The plan, not the Leader, provides the "rod" to which the lower-level controllers are connected as "wires".

Imagine a meeting such as a political Cabinet meeting or a meeting of friends who want to achieve some goal none of them can attain alone. By their interactions they may develop a plan that sets the references for the different supporting players. Leslie might say: "*If Janet does this, Bill does that, and I do the other, then together we can pull it off.*" There's no need for Leslie to be a Leader to tell Janet and Bill what they should try to achieve. What matters is that the players accept to be guided (have their reference values set) by the plan, though the plan may include a role for a Leader who controls for effective performance of the plan. This effect forms a thread through the rest of the book.

Collaborative Collective Control can, after all, have tensegrity properties just as much as can Coordinated Collective Control. The difference between them is that in idealized form they represent pure Anarchy and pure Autocracy respectively. Real collaborations are usually neither. A collaboration of equals often has a "moral leader" (such as Leslie in the example above) who may know a little more about the issue than do the others; a political Cabinet with a nominal leader who has selected and can fire the other Cabinet members still may well take advice from them when forming a plan that, by being a reference vector for supporting control structures, will act as a "rod" in a tensegrity structure.

Collective control can exist in any part of the continuum between the two extremes of pure Collaborative and pure Coordinated. An autocrat may require that all the subordinates accept the reference values in his or her personal plan[5]. A strong leader, on the other hand, may work together with a Cabinet to imagine flaws in any plan, finally selecting one that most consider to be the least of evils, and allowing for the kind of flexible execution implied by the PCT mantra: "Many means to the same end". The strong leader permits collaborative control of the plan design, which stabilizes the plan over time, whereas the weak autocratic leader has no such homeostatic network, and no stable plan that allows for the provision of effective values for the subordinates.

5. Although most autocrats seem to be male, not all are. When Margaret Thatcher was Prime Minister, a satirical British political TV puppet show had a sketch in which she was dining with members of her Cabinet. The waiter asked for her choice of entrée, and she said "Steak, bloody". When she was asked "And the vegetables?" her reply was "They'll have steak, too".

Chapter III.2. Autocatalysis and Side-effects

In this Chapter, we use the thoughts on homeostasis and control that were developed in the first two Chapters of Volume II to begin thinking about the kinds of organization that might naturally develop as a consequence of reorganization by individuals whose control actions create side-effects. We leave political issues until much later. We are still concerned with general properties of control, now concentrating on those effects that result in organization without the intention on anyone's part to create the organization. We will find autocatalytic loops in which the catalysts are side effects of control that alter the ease of control of some perception by a different person (or other organism). In Part 6, protocols allowed one person intentionally to reduce error in a perception controlled by another person. Now we dispense with intention.

In Part 5, we were much concerned with the need for variety among the types available for interaction, whatever the complexity of the basic types. Here, to begin with, those types are the roles individuals play when interacting with each other. It is all too easy to treat a role as the person who is playing the role, to treat the Chairman role as Jim Clark who happens to be currently designated Chairman, the janitor as Bill Patterson who is currently cleaning the office, the driver as Axel Furinger who is now driving this bus, and so forth. These individuals at other times, and sometimes at the same time, play other roles. Bill Patterson, who was performing the janitor role, may at the weekend play the role of Captain of a sports team, and so forth. They are the same person, whatever role they may be playing at the moment, and any of the the roles may be played by different persons at different moments. Jim Clark resigns as Chairman, Bill Patterson the team Captain falls sick; someone else performs the vacant role, while the role continues unchanged.

When one thinks of an organization, one might be thinking of a network of relationships among roles, or a network of relationships among persons. The concepts are different, as different as an organization chart is different from the network of friendships among the people working for the company. But the two networks are not independent, since the capabilities and knowledge of the person playing a role are central to how the role is actually performed. We do not go far into this here, leaving it until Chapter III.3 for further discussion, but the difference between role and person must be acknowledged when we seek the roots of organization.

III.2.1 Co-reorganization

In the passage quoted in the introduction to Chapter II.4, McClelland describes some examples of roles that are stabilized by collective control. It is obvious that the knowledge and abilities required for these roles are distributed unequally over the population, but we cannot argue from the existence of the roles to the conclusion that PCT predicts that roles will arise out of an initially undifferentiated network of interpersonal interactions in a "soup" of perceptions being controlled. The arguments in Chapter II.2 and Chapter II.3 may go some way toward the idea that they will, but those arguments are more suggestive than conclusive. We must look elsewhere for indications that levels of authority and distributions of social function arise naturally, if indeed they do, rather than being simply a result of randomly drifting changes of interaction patterns and genetically determined abilities.

That this is a real problem is highlighted by the existence within the same kinds of organisms (e.g. primates) some species that behave largely as social animals (e.g. humans, bonobos, chimpanzees, and gorillas) and some that become largely isolated individuals once they achieve adulthood (e.g. orangutans, known as "the Old Man of the Forest"), as well as some very different species that live mostly as isolated individuals, but come together under certain conditions to form a highly organized structure (e.g. slime-molds).

In an idealized, initially "flat", network, each individual controls many perceptual variables by influencing the physical environment, but has no special connections with particular other individuals other than through resource conflicts and side-effects that affect the other's control performance.

The unsocial species avoid direct conflict, and to a large extent also the problem of detrimental side-effects, by avoiding each other so that they do not attempt to control through common parts of the physical environment. Orangutang males apparently even signal their intended travel direction for the next day, and other males move away from that expected track (van Schaik et al., 2013), increasing their mutual isolation. Social species also reduce direct conflict, but they do it by reorganizing so that they largely avoid controlling through the same part of the environment, while at the same time collaborating to control collectively perceptions they could not control individually. Even orangoutangs can live sociably if they are raised together from an early age in a refuge run by humans.

It might seem unreasonable to suppose that reorganization would lead most individuals to avoid the worst side-effects of the actions of other independent individuals, as well as to avoid causing detrimental side effects to others. We do, however, have a small-scale experimental example of why it might happen. Powers in his "Arm 2" demonstration in LCS III (Powers, 2008) showed how a multi-level hierarchy of control units reorganized so that it could cleanly control different features of a 14-degree-of-freedom[6] arm model by orthogonalizing the perceptions controlled and the actions employed at each level.

The demonstration starts from an initial condition in which each control unit is connected with random weight to every degree of freedom, typically a joint angle in the arm, and therefore creating a high degree of mutual interference and conflict. By e-coli reorganization, the "Arm" arrives at a situation in which the individual ECUs control their particular perceptions with very little side-effect interference, at each level of perception. This "Arm 2" demonstration, in combination with the "Little Man" (Chapter xII.10), was the inspiration for the description in Chapter 1 of baby Len learning to make his synx approximate Rob's syncons by controlling his features independently.

This kind of communal tranquility of simultaneous operation can exist only if the environment provides a sufficient number of functionally independent environmental feedback pathways to allow each control unit to bring its perceptual signal near its reference value. In real life, this is rare. "Arm 2" had enough freedom of control to allow it to happen, but "Arm 2" operated in a uniform world lacking the kinds of fixed objects, obstructions, and nonlinearities characteristic of the world in which we live. Without such implied structural complexities that create the environmental tensegrity "rods" that become embodied in higher-level perceptions, reorganization would not build the kind of tensegrity control structure that we have argued is likely to characterize living control systems.

As McClelland points out, one of the role types of social organisms is a builder of structures that others can use as atenfels, thereby increasing the total number of perceptions that could be simultaneously controlled (Paths 1 and 2 in Figure III.2.2). But quite apart from this, the Powers "Arm 2" demonstration shows that the existence of interfering side-effects can be substantially reorganized away in a group of individuals that interact with each other over substantial periods of time. That the irregularities and structural coherences of our everyday world may induce tensegrity stabilization in no way diminishes the force of the "Arm 2" demonstration.

6. In this context we ignore temporal degrees of freedom, meaning that a degree of freedom in the arm is an independent joint angle, such as wrist rotation, elbow flexion, and so forth.

III.2.2 Types of interaction

People may interact in many ways. The kind of interaction usually discussed in the context of PCT is the "Conflict" interaction, in which two different control systems try to control perceptions of the same function of the environment, as shown in Figure III.2.1. In the Figure, the common function of the environment is called the "CCEV" for "Collective Corresponding Environmental Variable". This kind of interaction was called "Conflicted Control" in Chapter xII.13. In conflicted control, in addition to the standard negative feedback control loop of ECU 1 (s1→p1→e1→o1→(CCEV)→s1) and its equivalent in ECU 2, there is an extra positive feedback loop (s1→p1→e1→o→(CCEV)→s2→p2→e2→o2→(CCEV)→s1) that passes through both ECUs.

In a positive feedback loop with an integrating output function in at least one of the ECUs, any small disturbance that causes the error to exceed the tolerance zones of either of them is exaggerated over time, leading them both to produce ever-increasing levels of output until one fails. This positive feedback loop effect is countered by the two negative feedback control loops, so what happens to the CCEV depends on the balance between them.

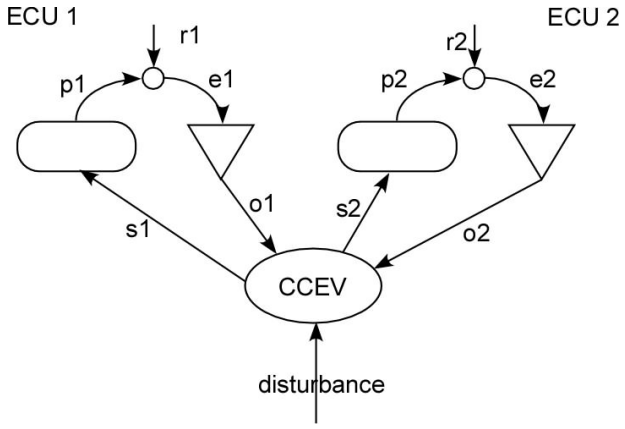


Figure III.2.1 A basic conflict situation. Two control systems perceive the same function of the environment, labelled "CCEV" for "Collective Corresponding Environmental Variable" by analogy with the CEV of a single control system.

McClelland (1993) presented a set of simulations of such systems. If the two Elementary Control Units (ECUs) have the same reference value for their perceptions, they act in concert to influence the CCEV as though there were just one collective controller with a loop gain equal to the sum of the gains of the individual controllers. If the reference values differ, however, the two control systems are in conflict. Despite the conflict, and even though the conflicted control systems keep increasing their outputs, the CCEV nevertheless is controlled against the disturbance exactly as though it were being controlled by a single virtual controller with a loop gain that is the sum of the two individual (negative) loop gains.

To an external Observer running the Test for the Controlled Variable who does not see the two individual controllers, the CCEV appears to be a CEV of an ordinary controlled perception, as McClelland (1993) demonstrated, and as we discussed for stochastic collective control in Chapter xII.13. But the omniscient Analyst knows that this controlled perception and its associated reference value cannot be located anywhere physical. They are *virtual*, detectable only to an outsider not involved in controlling a perception related to the CCEV. The Giant Virtual Controller controls a virtual perception to a virtual

reference value that is some kind of average of the real reference values of the real controllers who contribute to (are members of) the GVC.

In the case of two conflicted real controllers, McClelland (1993) showed that if the controllers have limited output power, as real systems do, then when the output limit of one of the controllers is reached, the CCEV becomes the CEV of the remaining controller.

Other nonlinearities will also influence the way the CCEV is influenced by a disturbance and the way that the members' reference values combine to form the virtual reference value. For example, the error in a control system is effectively zero so long as the perceptual value is within the tolerance zone, so while all perceptions lie within their tolerance zones the CCEV is influenced only by the disturbance, and appears as the CEV of a controlled virtual perception only when at last one of the real perceptions leaves its tolerance zone.

As we have seen, conflict is by no means the only possible interaction between control systems. All control actions have side-effects on parts of the environment outside the feedback loop, including components of a different control loop. Side-effects are unavoidable, though the better the control, the less energy is wasted in creating them. Figure III.2.2 illustrates some of the ways in which the side-effects of one person's control might affect another's ability to control.

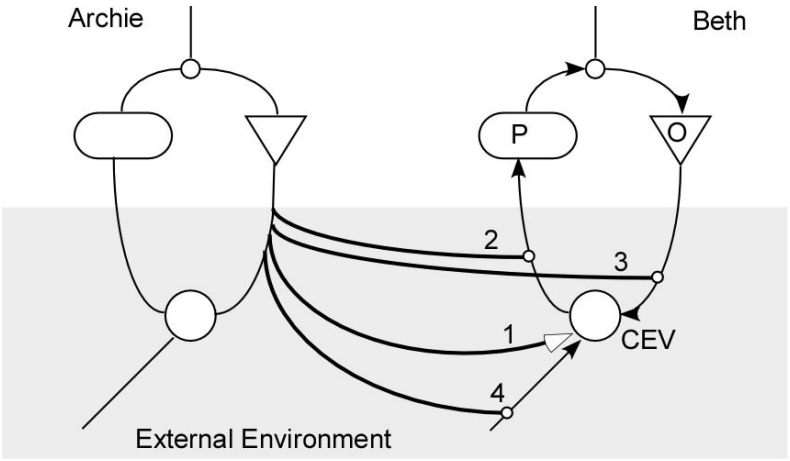


Figure III.2.2. Different ways Archie's actions might influence Beth's ability to control some perception. (1) Directly influence Beth's CEV, (2) Change Beth's ability to perceive her CEV accurately, (3) Change Beth's ability to influence her CEV, (4) Change the ability of external disturbances to influence Beth's CEV. The diagram shows Archie's influences as side effects of his controlling some perception, but the same possibilities exist if Archie controls his perceptions of those influences.

Not all side-effects create problems for other control systems. Some can be helpful if they influence the environment of another control system in a way that makes it easier for the other system to control. Helpful side-effect interaction is possible for interaction types 2 and 3 in Figure III.2.2, which influence the other system's atenfels, and type 4, which affects the ability of the disturbance to influence the other system's CEV.

Side-effects may be the effects of energy being expended on control, but they may also be the effect of the stability induced by control, as McClelland pointed out in the extended quote. For example, a road labourer might help pave a dirt road, being paid for the work and thereby controlling his perceptions of

available money, while at the same time having side-effects on the ability of many unknown people to control a variety of different kinds of perception by means of driving along the road. Or one person might hold an umbrella over her own head, while unknowingly holding it over the head of someone walking close, thereby preventing a possible disturbance by rain or sun from influencing a perception the other might control.

The types of interaction differ in the way the side-effects of Archie's controlling affect the quality of control in Beth's loop:

Path 1. Directly influencing Beth's CEV simply adds to the disturbance to her CEV. If, as would usually be the case, Archie's side-effect variation is uncorrelated with Beth's disturbance variation, Beth's quality of control against the basic disturbance would be compromised. If, however, the same basic disturbance is a component of the total disturbance to Archie's CEV, Archie's output might possibly assist Beth's control. This possibility is sufficiently improbable compared to the probability that other kinds of side-effect influence from Archie's control will help Beth's control that we ignore it, and say that Type 1 side-effect influence is usually detrimental to Beth's control.

Path 2. A side effect of Archie's control enables Beth to perceive the CEV more accurately or faster than would otherwise have been the case. The opposite is also possible, and perhaps more probable, in that Archie's control could make it more difficult for Beth to perceive her CEV accurately. Either way, a type 2 side effect alters the effective loop gain and/or the loop transport lag in Beth's control loop.

Path 3. The side-effect of Archie's control make it easier or more difficult for Beth to influence her CEV accurately or speedily. As with type 2, a type 3 side-effect interaction affects the loop gain and/or transport lag of Beth's control loop, either improving or degrading her quality of control.

Path 4. Archie's side effect alters the path between the source of the disturbance and the influence that disturbance has on Beth's CEV, either reducing its effect (shielding) or increasing its effect (enhancing). An enhancing effect differs from a type 1 side effect on Beth's CEV, because a type 1 side effect matters only as its magnitude varies on a time scale like that of the basic disturbance, whereas a type 4 side-effect can be static.

Examples such maintaining a road that are mentioned by McClelland in the extended quote in the introduction to Chapter II.4, are stabilities that by their very stability enhance the quality of control by potentially many other control loops. They are atenexes. At the same time, however, their stability could detract from the quality of control in some other loops. A well maintained road, for example, is likely to carry more traffic than an ill-maintained road, which reduces the ability of hikers to walk or wild animals to forage and hunt freely and safely over their domains.

While the side effects of Archie's control can influence the quality of Beth's control, Beth's side effects may loop back to influence Archie's quality of control, either directly or because of their effects on some third control loop. We saw half of an example of this in Section II.10.1, when baby Ivan's actions in controlling the positions of his arms, legs and voice had side effects that produced a type 1 influence on Cora's controlling for perceiving Ivan to be contented. Cora's only available actions were to influence something that Ivan was ineffectually controlling, such as the perception of hunger or a pin-prick, for both of which he had a reference value of zero.

Here is a contrived example from the everyday world, in which side-effects create a loop that benefits both controllers. A farmer controls his perception of available cash, for which he has a high reference value, by selling the good crop on which he bestowed fertilizer. He may well know that the result of selling the crop is that food will become available in stores, but he probably does not control that perception. For all he cares or knows, the purchaser of his crop might dump it in a landfill. For the farmer,

food that arrives in the stores is a side-effect of controlling his perception of the amount of cash available to him.

The existence of food in the stores makes it easier for a city-dweller unknown to the farmer to control her perception of food on the table, which she can do by using a complex of protocols collectively called "shopping". A side-effect of her shopping is that a little money will go to the farmer she doesn't know, and he will be able to use that money to make it easier for him to get the fertilizer to help him to control his perception of a good crop next year. A side-effect of the farmer's perceptual control eases the shopper's control, and a side-effect of the shopper's perceptual control eases the farmer's control (Figure III.2.3). Neither is aware of the other's existence as an individual, but their side-effects are mutually supportive. Both control better than they could if the other were not there.

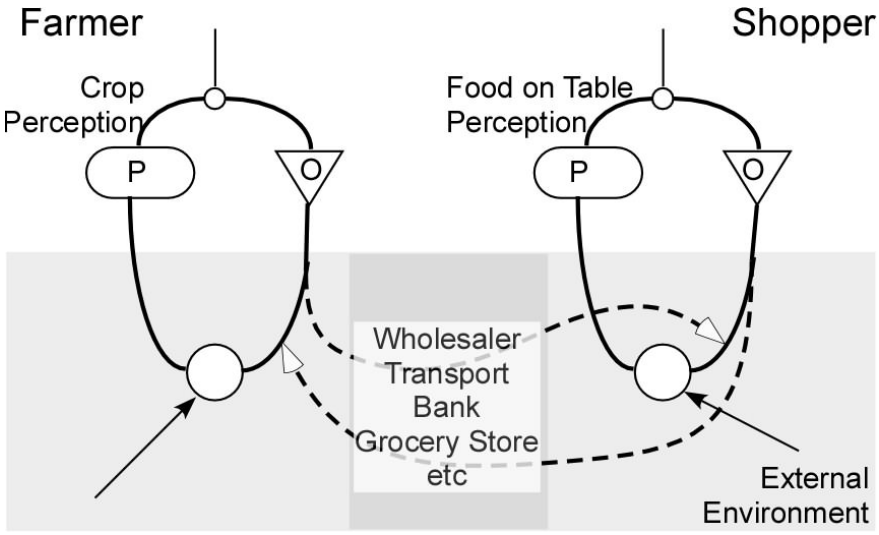


Figure III.2.3. A side-effect feedback loop between two people, in which the side-effects of each person's control action influence the other's ability to control, through the medium of the many control systems in many people who work in the various business shown in the central panel.

The farmer-shopper example illustrates a kind of interaction among control systems that might be called a "beneficial side-effect loop", which is not detectable by the controllers involved, but might be seen by an Observer or an Analyst. Such an interaction loop might have been the original way multicellular life came into existence, one cell disposing of waste that another could use.[7] Antarctic Penguins use a loop of this kind, in which the waste product is heat. By huddling together, the heat waste product of each penguin's internal control systems helps its neighbours in the huddle to survive the winter.

Another kind of beneficial interaction between control systems is "shielding" (4, in Figure III.1.2). The concept of a shield is straightforward. If a shield is present, the influence of some disturbance source on a variable is less than without the shield. An umbrella is a shield that reduces the effect of rain and sun on the skin. The skin is a shield that reduces the effect of a myriad external events on the cellular systems inside. A control system controlling the perception of a shielded variable is better able to control than if the same variable had no shield.

7. We suggested another possibility in Section II.4.9

Shields need not be so obvious as an umbrella. Indeed, a shield may merely reduce the influence of the disturbance source on the environmental variable. A thermostat controls its own temperature, and thereby reduces but does not eliminate the influence of outside temperature fluctuations on the air temperature of the room that contains it. A person sensitive to temperature fluctuation may still put on or take off a light sweater, but not a parka suited to Arctic temperatures. As another example, choppy waves make it difficult to handle a small boat, but one can "pour oil on troubled waters", shielding the boat-handler from the worst of the disturbances that would otherwise be induced by the wind. The waves may still be turbulent, but they will not be as bad as without the oil.

The shielding effect may be an environmental variable that corresponds to a controlled perception, as, for example, when one person deliberately holds an umbrella so as to perceive a friend being shielded from the rain. Or it may be a pure side-effect. The following contrived example shows shielding as a side-effect loop, in which the side-effects of each member of the dyad provides a shield that reduces the effects of disturbances to a perception the other controls.

Imagine that a cook was trying to fry something on a small boat in a choppy sea, but the boat motion caused cooking oil to spill overboard. The boat handler's control has become easier and the boat motion is smoother as a side-effect of the cook's imperfect control of the frying. But as a side-effect of the improved control on the part of the helmsman, the cook's control of creating the meal is improved. The two side effects form a beneficial side-effect loop (Figure III.1.4).

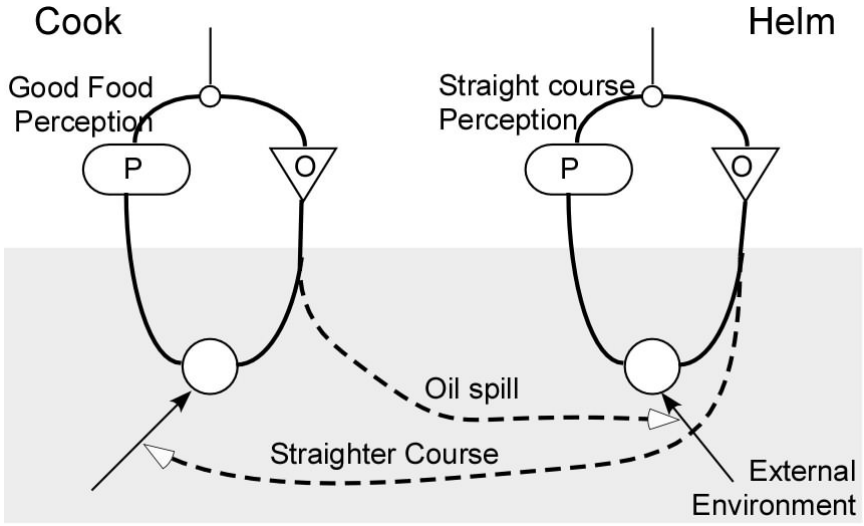


Figure III.2.4. A beneficial side-effect loop through shielding the CEV from the influence of disturbances. Both controllers control better if the disturbance effects are reduced.

A feedback loop can also be produced by an interaction in which Archie's control has a side-effect that influences a perception Beth controls (interaction type 1 in Figure III.2.2), while Beth's control action side-effects in turn influence the perception Archie is controlling. Figure III.2.5 shows this kind of side-effect loop, which is the loop on which protocols are based.

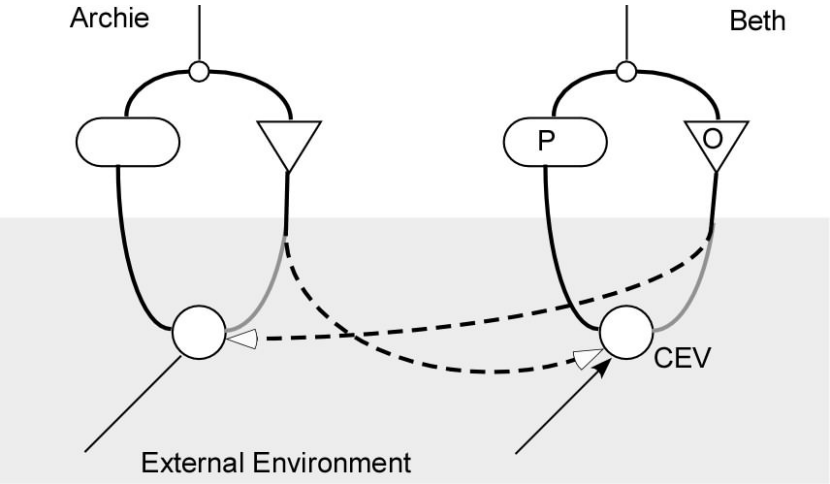


Figure III.2.5. A side-effect feedback loop between two people, in which the side-effects of each person's control action influence a perception being controlled by the other. The situation could result in an escalating conflict of which neither is aware (if the loop gain is positive and greater than unity), or could be to the benefit of both (if the loop gain is negative).

The sign of the feedback in a side-effect loop might be either positive or negative. Neither party may be aware of the benefits they receive from the other, nor, if the feedback loop gain is positive, might they be aware of the source of what the Analyst would see as an escalating conflict, though not a conflict over a CEV they are both trying to influence.

Up to this point we have considered only side-effect loops in which both parties have the same kind of influence on control by the other — both influence the other's CEV, or both shield the other from disturbance, for example. But other loop types are possible in which the two parties have different kinds of influence on each other's control. We could give loops through two people names based on the types of influence shown in Figure III.2.2. For example, in a 3,4 loop, Pat influences Mike's atenfels, whereas Mike's control action shields Pat's CEV from disturbances. There are thus sixteen possible kinds of side-effect loops involving two controllers. Only a few of these loop possibilities are important in what follows, and we will not distinguish them except insofar as the loop gain is positive (inducing conflict) or negative (mutually beneficial).

A beneficial side-effect is one that eases control by a separate control system. Functionally, it is a catalyst, for two reasons. Firstly, we can consider the relation between a perception and the corresponding environmental variable as a reaction between two "elements" in the soup of Chapter II.2. It takes energy to reduce the entropy of a controlled variable, just as it usually does for a molecular reaction that requires catalysis. Secondly. improvement in control implies an speed-up in countering disturbances, which, for any specific disturbance source implies that a higher-level controller that uses the speeded one has more capacity to spare in countering disturbances from other sources. Both the energy-entropy relationship and the speed-up mimic the functions of a catalyst in molecular interactions, so we should expect the possibility of autocatalytic loops, and thence homeostatic loops, some of which might themselves be control loops evolving in a "soup" of control systems.

III.2.3 Side-effect Loops

Next, we argue that not only is it likely that interfering side-effects will be reorganized away if individuals just go about their business of controlling their own perceptions, but also it is very probable that if the group is large enough, an autocatalytic homeostatic structure will occur that greatly enhances the ability of most of the individuals to control more and more perceptions by using the rare beneficial side-effects of control by others. Furthermore, these processes can, but need not, result in the creation of distinct social groups that function differently but internally are largely cooperative. The proviso that the group be large enough is not a strong constraint, as "large enough" probably means more than a few tens, but less than a few hundred individuals (Section II.2.2).

It is probably true that most side-effect interactions are simply disturbances to other CEVs (type 1 of Figure III.2.2), but there is a greater than zero probability that whatever the action, it will make someone else's perceptual control easier or more precise through one of the other paths, as shown in Figure III.2.6. We might call this "being inadvertently helpful".

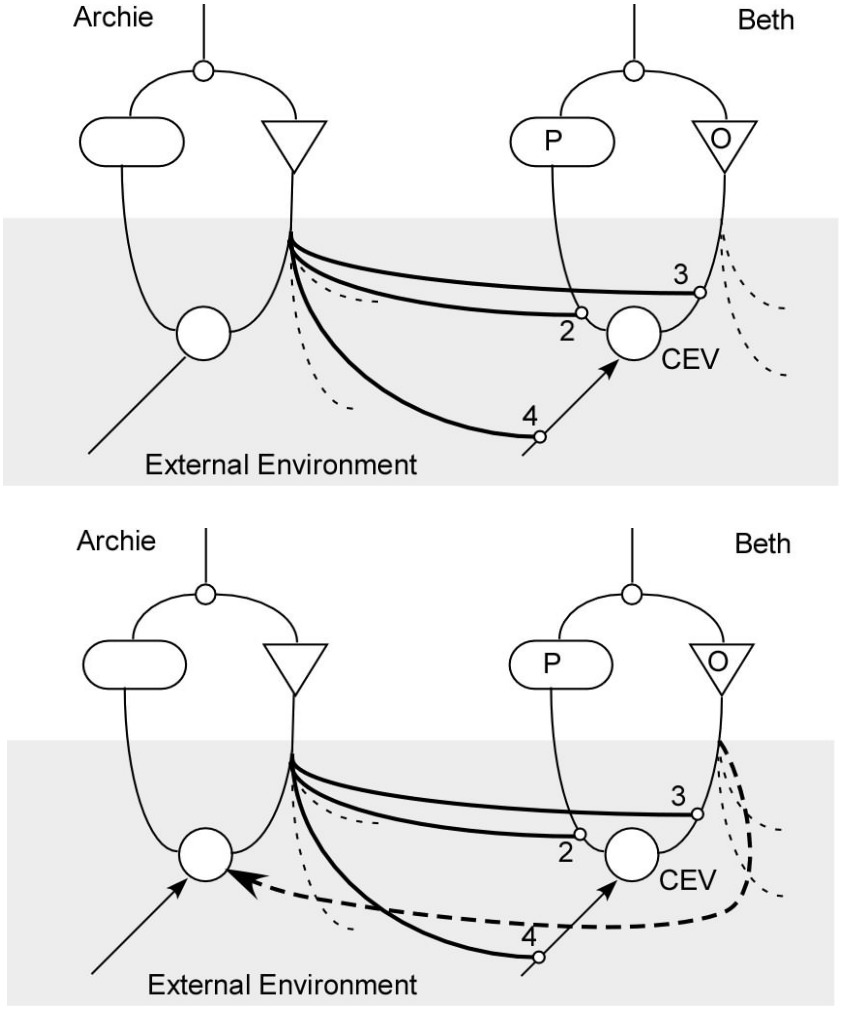


Figure III.2.6. (a, above) Figure III.1.2 eliminating path 1, to show only ways the side-effects of the actions of Archie's control system might influence Beth's ability to control, excluding direct disturbance to Beth's CEV. Dashed arcs suggest that the side effects may influence many other people; (b, below) Beth's easier control is likely to reduce any side-effect, including any side-effect disturbance her actions might have had to Archie's CEV, thus easing Archie's control.

Archie's action in controlling some perception could, of course, make it harder for Beth to control her affected perception, but if that happened, Beth would be likely to reorganize. Over a population, reorganization in all the individuals will tend to reduce the incidence of deleterious side-effects, just like those in Powers's "Arm 2" demo (Section III.2.1). However, the chance that Archie's actions will be inadvertently helpful to at least one person increases proportionately to the number of people in the group. Archie's controls that produce side-effects helpful to Beth are less likely to be reorganized out of existence, because Beth's easier control means she produces less side-effect disturbances to others, including, though she does not know it, Archie.

A contrived side-effect example may illustrate path 4, "shielding". Beth is controlling for staying dry, but it starts to rain. Not having an umbrella, she would probably try to shelter in a shop door or somewhere with an overhang. Archie has unfurled a big umbrella, and Beth walks unobserved close behind him. Beth is shielded from the disturbance as a side-effect of Archie shielding himself. In this case, Beth's controlling for perceiving herself dry has no obvious side-effect on Archie's control, so the dashed arc in the lower panel is not directly involved. But it might ease control of some perception controlled by Charlene, who may be waiting at home for Beth to arrive.

Beth may be walking in the rain because Charlene called her to come and help with something. So Archie's shielding himself from the rain actually helps Charlene. Perhaps whatever Charlene wants Beth to help with could have the side effect of making Daniel more able to control a perception, the side effects of which make it easier for Evan to control some perception or other. Maybe person Z in this chain is helped to do something such as making waterproof boots that make it easier for Archie to go walking in the rain.

Of course, the specific instances in this example are one-shot occurrences, and it is unlikely that Beth would on another occasion encounter Archie when she was going to see Charlene while it was raining when she was had forgotten to take an umbrella. But one-shot events are the basis of stochastic collective control, and the principle applies also to ongoing and repeated activities.

As the saying goes: "What goes around comes around", and loops of beneficial side-effects can occur. Figure III.2.7 suggests such a loop, which the beneficent influences occur through a variety of the pathways of Figure III.2.6, none of which involve path 1, a direct side-effect disturbance to another's CEV.

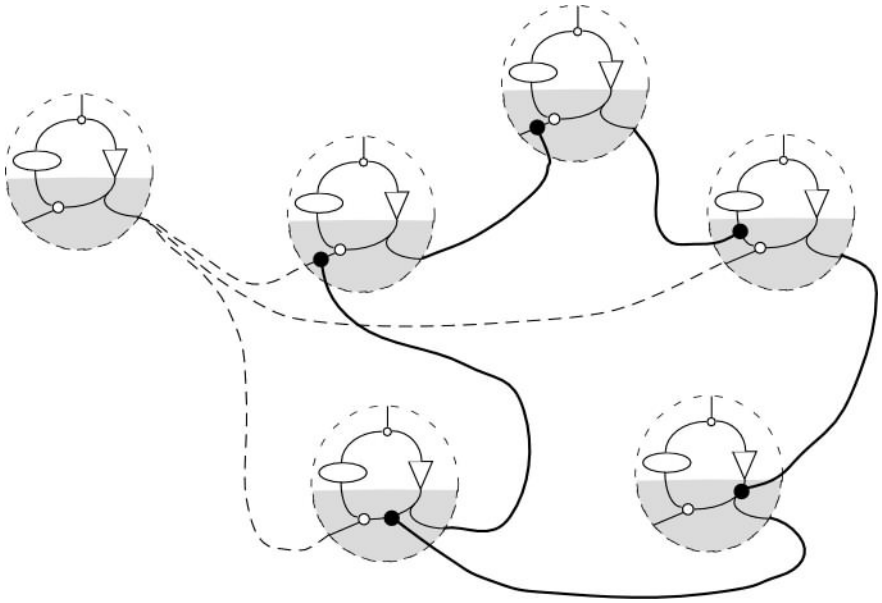


Figure III.2.7 A loop in which 5 control units each have a side effect that benefits another's control, so that around the loop the first one eventually benefits from the side effects of its own control. Some of the 5 are disturbed by the side effects of control by a unit outside the loop. The side-effect loop improves the ability of each to counter this disturbance.

Although it may be unlikely that the side effects of a particular control action will actually make a particular perception in a particular person easier to control, yet the probability is greater than zero. In a not very large population of say, 300 people, a probability even as low as one in ten thousand makes it almost certain not only that at least one such relationship occurs, but also that at least one loop of beneficial side-effects will exist (Figure II.2.6).

It is useful at this point to note that the earlier discussion of the development of new controllable perceptions applies here with full force. A person (Vera) who benefits from belonging to one or more loops probably will not be able to perceive any loop as a whole, but is likely to learn to perceive what someone else regularly does that enhances her ability to control. That person's behaviour is an atenfel for Vera's control that it benefits. Vera might perceive the other as a person or as a role — a shopkeeper, a road-worker, a bank teller, or whatever — but if their actions are helpful, Vera is likely to control for using their services and thereby improve their ability to control (e.g. by continuing to be paid for their work). To the extent that this happens, the side-effect loop is complemented by direct effects that work backwards around the loop. These direct effects enhance the stability of the individual side-effect links by creating a local hybrid loop, part side-effect and part direct effect.

The servers at the same time can learn to perceive that their work helps the person served, which may or may not be a perception that they control. No one member of a loop may be able to perceive the loop as a loop, but any one of them might perceive their influences (or some of their influences) on their neighbours within the loops, and then could control those perceptions. Turning the side-effects into controlled perceptions makes the loops much more stable than they otherwise would be, since side-effect influences are subject to all the vagaries of environmental variation, vagaries that are opposed by the fact of control.

If a hybrid loop has only two stages, when both parties are controlling for the other's improved control, the (no longer hybrid) loop has most of the characteristics of a trading motif (Chapter III.6ff.). If

it is longer than two stages, the behaviour of any controller in the loop has all the overtly visible characteristics of altruism. The numerical argument suggests that altruism, far from being a mystery to be explained, is likely to be a property found among the members of any sufficiently diverse ecology. Genes that dispose their organism to control for the welfare of others are likely to live in organisms that form parts of beneficial (control-improving) loops, which enhances their likelihood of long survival, despite on the surface doing something that could be detrimental to their survival.

Do we here see a glimmer of insight into the phenomenon of martyrdom, or for "*dulce et decorum est pro patria mori*" under which motto millions have died in wars throughout history, both before and since Ovid wrote that encouragement to self-sacrifice? The individual bodies may die, but the genetic and, we will argue later, social structures that lead one to lay down his or her life for another or for a "greater cause", those structures are more likely to survive than if the martyr had stood aside. They survive because the roles form part of a homeostatic side-effect loop, or rather, of a highly evolved homeostatic network with many loops that support each other.

III.2.4 Control, Tensegrity, and Homeostasis

Is a simple homeostatic loop a tensegrity structure? No it is not, but a more complex homeostatic network might be. Why is this? The simple loop cannot be a tensegrity structure any more than can a simple control loop, because in each case change in the value of any one variable is propagated through the loop one variable at a time, whereas a tensegrity structure works because of the distribution of load in parallel over several wires or rods at each junction point. All the junction points in a tensegrity structure pass the effects on them back into the structure. A simple homeostatic loop does not distribute the effect of changing a loop variable at any of its junction points. It may distribute some effects by way of side-effects, which is the topic of this chapter, but those are not effects distributed within a simple loop's feedback system.

To create a tensegrity structure requires more. In Figure 8.17 we created a modular tensegrity structure by incorporating multiple control loops into a second-level control loop (Figure 10.8) and carried the process further into a three-level structure in Figure 8.18 and then constructed a minimal fully 3-D hierarchy (Figure 8.20). We obtained a tensegrity-like effect by linking at least two first-level control structures into a second-level structure. So is the requirement for homeostatic tensegrity the provision of multiple levels of homeostasis? No it is not, any more than the construction of multiple levels is a requirement for a physical tensegrity structure. The minimal 3-D physical tensegrity structure of Figure 8.19 attests to that.

Taking a leaf from the discussions of stiffness and tensegrity in Chapter 8, we might ask whether a structure of interlinked homeostatic loops with no hierarchic relationship can form a tensengrity structure. We already understand that a hierarchic set of homeostatic loops can, because a control loop is a form of homeostatic loop, but can a "flat" set do so too? Intuitively, this should be possible, but can we show how it might be arranged either when the individual loops share a common catalyst-producing reaction or when they are quite independent? Yes we can.

The core of tensegrity is the distribution of countervailing forces throughout a structure. Something "pushes" on a point where other things "pull" in different directions. This is exactly the situation addressed by McCelland (1993) when he demonstrated the Giant Virtual Controller inherent in a dyadic conflict. Conflict, however, need not exist in a two-level structure such as that of Figure 8.17, because the "rod" that keeps the reference values for two control loops separate even when they appear to control a related perceptual variable is the structure of the higher level perception, built by reorganization within the hierarchy.

In this sense, even the physical tensegrity structures of Figure 8.6b and Figure 8.19 are “flat”, having no hierarchy of tensegrity structures as components of the larger tensegrity structures. In them, conflict is evident at every vertex, the wires straining to pull the rod end, the rod straining to avoid being pulled. By analogy we might suspect that no flat homeostatic network could show tensegrity without conflict.

Figure II.3.3 showed one node of a homeostatic loop, a reaction process (which we will see as a control process later) that produces two outputs, one of which provides a catalyst or anticatalyst for the next reaction in the loop, while the other output is waste, a necessary byproduct of an entropy-reducing operation, which all these reactions must be. The Figure does not show the through energy flow, which provides a necessary extra input and output for each reaction process.

The waste may be in the form of energy that is distributed in concentrated (low entropy) form or in material form, such as a pebble that is dislodged by a step on a gravel path. Either way, if the reactions are actually control loops (and control is the central topic of this book), the waste product may have a side-effect on other control loops by any of the paths of Figure III.2.2.

In contrast, the main product of a control process is a stability of the shared environment, or at least a reduction in the variability caused by a disturbance. This stability itself could be the catalyst for the next control loop in the homeostatic chain. The variability in the CEV that remains might in absolute terms act as an anticatalyst to the next control loop, but the strength of that anticatalytic effect would have been reduced by the action of the earlier control loop. The added stability, not the remaining variation, is what produces the side-effect on the next control loop.

None of this affects whether a homeostatic network could be a tensegrity structure. That depends on what happens because of the distribution of the side effects. These side-effects might affect the quality of control (QoC) of any controller acting on anything in the shared environment, including other controllers in the local homeostatic loop. An effect on another controller in the same loop produces a parallel branch path in the loop.

A branch path that rejoins the main path at some place in the same loop involves a junction with one input and at least two outputs, and a junction with at least two inputs and one output. This is the minimum requirement for the existence of a tensegrity structure, but the two-member sides of the junctions would have to have both catalytic and anticatalytic effects, and they would not be very effective, because one would have to work directly opposite to the other. The same would be true of any complex branching path, including ones that included other loops that shared a common reaction process. The overall effect is that there is only a single path around the loop. no matter how it is branched.

Only when considering connections among otherwise independent homeostatic loops are tensegrity structures viable. In this case, there is a possibility for an inhibitory anticatalyst in one loop to be opposed to a catalyst in the other. An opposition between a “push away” and a “pull toward” is a minimum requirement for an emergent tensegrity property, but it is not a sufficient one, because it does not allow for the distribution of the influence of an external disturbance. For that, as we said above, an opposition of at least two of one kind against one of the other kind is required at each node point that contributes to the tensegrity property.

This multiplicity requirement indicates that tensegrity cannot emerge in a one-dimensional universe. Can it emerge in two dimensions? Figure 8.6a suggests that it might, if the bent compression members are replaced by a pure “push-pull” structure such as that of Figure 8.7. How can this be implemented in a network of homeostatic loops?

A vertex in a diagram such as the parallelogram of Figure 8.8 (modified here as Figure III.2.8) is equivalent to a reaction in a chemical homeostatic loop, or in the context of this Chapter a control loop

whose Quality of Control is affected by a side effect of another control loop. Catalysis is a side-effect that eases control, while anticatalysis is one that makes control more difficult or less precise.

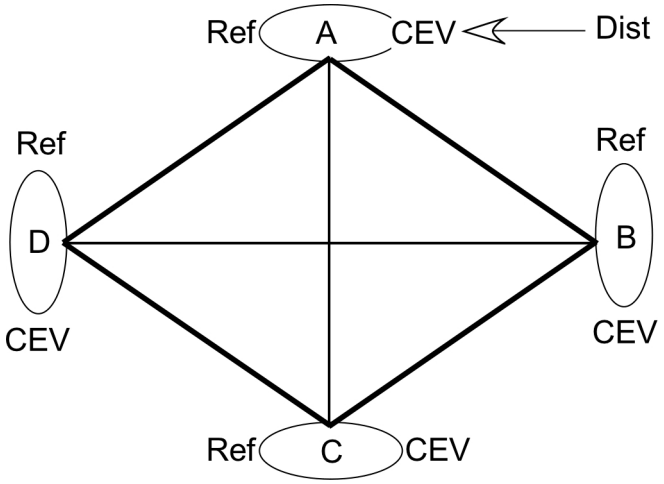


Figure III.2.8 The tensegrity parallelogram of Figure 8.10 when the vertices are control loops. Only Loop A is shown with a possible disturbance input, but any control loop may be affected by disturbances to its CEV.

In the parallelogram structure there are four vertices, each of which might represent a control loop (or a longer homeostatic loop). The parallelogram structure suggests that each is influenced by the side effects of all three of the others, either by two beneficial side-effects and one detrimental side-effect, or the reverse. Each of the loops shown by the ellipses could equally well be any kind of homeostatic loop. This set of interrelationships exhibits the tensegrity property, in that the influence of any outside effect on the ability of any of them to maintain stability is shared among them all.

The structure of Figure III.2.8 differs from the tensegrity structure of Figure 8.8 or the more complex one of Figure 8.6a in that the tensegrity effects of Chapter 8 are based on the existence of higher-level units in the perceptual and/or the real world environment. The structure of Figure III.2.8 does not. Each of the four control loops controls its own perception, which might be of a quite different level and type from any of the others. As a unit, the structure is "flat", meaning that it will exist at a single level of any potential hierarchical structure.

Larger such flat tensegrity structures exist – an analogue of the Figure 8.6a 2-D tower is an example. We have not yet, however, shown that the parallelogram is the simplest possible tensegrity structure of a homeostatic network. This we now do.

One noteworthy feature of the parallelogram structure is that each connection is bidirectional, which means that if A inhibits B, B also inhibits A. In practice, these effects need not be direct. The link in either direction could go through any convoluted pathway, so long as the result is that of mutual inhibition or mutual enhancement. The structure has 12 directed links, not 6 undirected ones.

For tensegrity to work in two dimensions, the stress on each compression component must be distributed over two tension components, or vice-versa, each junction need three components, in this case side-effect influences. Hence for a structure with four control loops, a 12-link structure is minimal. Furthermore, since each control loop requires three influences from different sources, the structure of Figure III.1.8, which contains four control loops, is indeed a minimal tensegrity structure.

If the cross-members of the parallelogram are the compression components, it has two "rods" and four "wires". In three dimensions, the minimal "flat" (non-hierarchical) tensegrity structure of Figure 8.17 uses three rods and nine wires, which suggests the possibility that in N dimensions a minimal flat tensegrity structure needs N rods and N^2 wires. An intuitive justification for this suggestion is that N rods are required to span the N directions of the space. If each rod end is connected to one end of each other rod by a wire, N^2 wires will be needed.

Is such a complete connection set required to ensure that the structure is stable? The requirements for tensegrity are only that the load in each compression member be distributed over at least two tension members, but the minimal 3-D structure requires three for stability. Cut any one, and the whole structure collapses, because the rod ends connected by the cut wire can now move further apart in that direction, reducing the stresses on their remaining connecting wires. The same is likely to be true in N dimensions; each rod must be constrained in all N dimensions. This intuitive argument is far from a mathematical proof, but it is at least suggestive.

Regardless of the minimality of the structure, the example of Figure III.2.8 shows that a flat system of homeostatic loops can exhibit tensegrity through the side effects of waste or of loop stability by distributing over the rest of the loops in the system the influence of a disturbance to any one of them. Such a system is resilient, even if the cross-influences among the homeostatic loops are pure side-effects, unperceived by any process in the loops themselves. In particular, when the interconnected homeostatic loops are control loops, none of the structure that keeps them working together need be perceived by any of the individual perceptual functions. That is the nature of side-effects.

If we now consider the informational channel capacities of such a flat tensegrity structure, we see that information is distributed indirectly over parallel channels through the network, but in a minimal structure directly by only one link. We will consider the implications of this when we look more closely at what the NATO Research Study Group IST-085 called "relativistic networks", and consider the concept of "mass-energy" in and of a network.

III.2.5 Different social behaviour of related species

Do we yet have the start of an answer to the question posed at the beginning of this chapter: Why do related species often have very different social structures? Among primates related to apes, why do we have at the same time solitary orangutang, male-dominated social gorilla groups, peaceable female dominated bonobo groups, aggressive militaristic and territorial chimpanzee clans, and gregarious humans that form much larger groups that engage in genocidal warfare?

The start of an answer was offered at the beginning of Chapter 11: the way the elemental "soup" develops into an autocatalytic network. The "soup" starts out with isolated elements floating around in regions with different concentrations. Some of the elements react easily with others to form complexes, and others may catalyze or anticatalyze various other reactions.

The more complexes are formed, the more chances there are that some of them will catalyze some reaction or other, and the more different catalyzed reactions between elements and complexes there will be. Small clusters of reacting and catalyzing groups form, and those that tend to hang together for whatever reason will tend to survive longer than those that go their own way. Small clusters may combine and dissipate, until at some point an autocatalytic loop appears and the population of all their complexes explodes, limited only if somewhere in the loop there are an odd number of control loops that produce inhibitory anticatalytic side-effects within the loop.

It is neither analogy nor metaphor to say that when the catalyst product is a side-effect of control, the functional relationship is the same whether that side-effect be immediate use of the energy distributed by control into the environment along with the rejected entropy that control requires, or a delayed stigmergic residual effect of some environmental variable having been affected by control, or a maintained stability of the kind described in the extended quote from McClelland. We should expect some of these side effects to ease unrelated perceptual controlling, some to make other perceptual controlling more difficult, but most to have no clear effect elsewhere in the environment.

McClelland mentions the possibility that stabilized environmental variables can inhibit as well as enhance perceptual control in a paragraph that follows immediately the passage quoted in Chapter II.2:

> *An important fact to remember about all of these kinds of work is that while the feedback paths stabilized by a given kind of work can facilitate the control of perceptions compatible with the purposes of a particular social structure, these stabilized feedback paths at the same time are likely to make the control of an array of other perceptions more difficult, or perhaps even impossible, because the perceptions facilitated by the work are incompatible with the control of these other perceptions in that environmental space. For example, workers in extractive industries for strip-mining coal or producing oil from shale use heavy machinery to remove whole mountaintops or large tracts of forest, along with all the plants and animals that formerly lived in those habitats. While that work can provide the necessary feedback paths for other workers to extract and process the coal or shale oil, this removal of plants and animals and disruption of the physical landscape makes it impossible for people to control their perceptions of outdoor activities—like hunting, fishing, hiking, or logging—that depended on feedback paths no longer available in the disrupted landscapes. In sum, when we understand work activities as stabilizing feedback paths for controlling certain perceptions, we see that these activities can have a downside, as well as an upside, by limiting the opportunities for people to control other perceptions.*

To which we might add such collectively controlled activities such as protests that barricade public streets, or the fortifications that in mediaeval times impeded an enemy's access to a walled city. We have seen, however, that the introduction of anticatalysts such as these into a loop need not be considered a downside. For some, they clearly reduce the ability to control, but for the more general society, the inhibition induced by these actively maintained stabilities may simply produce a wider stabilization of many variables that could otherwise be a part of a runaway autocatalytic loop, which usually would present a much greater "downside".

In the creation of novel complexes during the development of autocatalytic or homeostatic loops in a "soup" of relationships, we should expect to see exactly the same kind of distribution of solo "elements" (now entire control loops or organisms) as in the chemical soups of Chapter II.2 and Chapter II.3. At different stages of development, we should see small clusters of elements that come and go, leading eventually to one autocatalytic loop or network that may split into mutually inhibitory sub-networks reminiscent of species. What we should not expect to see is the initially "flat" soup of elements remaining flat for very long.

In the case of the different species of primates, we see a small-scale example of such a distribution. Would it have been possible by examining the ancestors of early species of *homo* to tell that one of them

rather than a descendant of an ur-chimpanzee or another ur-ape would turn into the solitary orangutang and which into the uninhibited autocatalytic *homo sapiens*? I doubt it, but the concepts described in Chapter II.2 do offer a hint as to what did make the difference — language, and the development of a sufficient variety of protocols enabled by recombinant language.

Why language, and why recombinant language in particular (language in which it is possible to say meaningful things that have never before been said, by combining the elements in a new way)? Remember that in the first exemplar of autocatalysis, the critical factor for forming a loop or an autocatalytic cluster was reaction rate, the likelihood that two of the elements in the "soup" would react to form a complex that would not decay too rapidly, and that the effect of a catalyst is to increase the reaction rate.

In recent Sections we have been considering the analogue of a chemical reaction to be the ability to control a perception by influencing the environment. The "reaction" is the convergence of a perceptual function on the form of some property of the real world environment that can be influenced by action. That convergence may decay, just as will the complex produced in one of the elementary reactions, if it is not useful in maintaining the homeostatic loops of intrinsic variables that we hypothesized to determine the rate of reorganization (Section II.5.5). As McClelland pointed out in the long quote, it takes continuing work to maintain a stability of the environment.

This is true for every complex organism, so what might be different among the many species descended from the first ur-ape? One obvious hypothesis is that communication among the members of the species, or with members of other species, enhances the survival probability to an age at which descendants can be produced. Communication does not require protocols, but it does require the perceptual control of displays that can be readily distinguished by the partner, as suggested by the story of mother Cora and baby Ivan in Chapter II.9 or the development of multi-dimensional trajectories in Chapter 1.

If these displays keep changing, the benefits of the communication in stabilizing the homeostatic loops may be lost because the partner does not know the import of the display. If a watching bird changes its song from the song that means "leopard" to the song that means "snake", how will the prey ground-dweller know which evasive or defensive action is likely to be effective?

According to the Analyst, but probably not to the bird, the reorganization rate, and thus the control loop survival rate, depends on consistency, first of the initial display, and secondly of the defensive or evasive loop that has as part of the perceptual context the song of the bird. The bird, however, may also be communicating with others of its kind, creating the kind of side-effect loop that we have been discussing. Its benefit in catalyzing the ground-dweller's defensive control loop are a side effect of that side-effect loop's stability, not just of the bird's control loop that is active during its singing.

If we change our focus back to the "soup" of apes and species of *homo*, we can assume that all of these ancestors and relatives were able to communicate to their conspecifics at least as well as the bird communicates with the ground-dwelling prey or with neighbouring birds. We know also that at least some chimps and gorillas (and parrots and dogs) can understand quite a few human words. Porpoises may do even better with their own speech among themselves, but little is known about that. What we have not observed is a chimp putting together a phrase and using the entire phrase as a unit in constructing a larger linguistic unit, in the way that any child over the age of perhaps four or five will do with ease.

The introduction of recombinant language is an invention, maybe genetic based around the influence of our particular version of the *foxp2* gene, maybe not. In a soup of communicative interaction types that sustain homeostatic loops through their side effects, inventions are to be expected. Such inventions ordinarily are of structures (complexes) that use existing structures as construction materials.

Recombinant language is of this nature, but it could be maintained only when it became a catalytic component in a novel homeostatic loop. Otherwise, each time it was re-invented, it would decay away into the soup of non-syntactic language fragments.

Once recombinant language became a catalytic link in a homeostatic loop, what else might be in the loop? Immediately, one might guess that a new flexibility in the forms of cooperation, particularly in the invention of novel protocols that allowed homo sapiens, but not other species, to negotiate the navigation of a variety of situations that would be either imperceptible or solvable only by force (compare the difference between selecting the alpha male by fighting as opposed to selection by election). It is easy to guess possibilities, but much harder to determine what actually happened when the first autocatalytic loops based around recombining language exploded into being. The creative results of autocatalytic invention are unpredictable.

When enough different autocatalytic loops have formed, they are likely to have cross-influences, which can have all the forms that the interactions among simple control loops can have. The side-effects of actions in the different units of one loop may affect the variables directly, or they may influence the properties of any of the paths in any of the "reactions" of the affected loop, enhancing or inhibiting their effects, and strengthening or weakening its resistance to disturbances. We described a form of this in Section III.2.4.

But there is another way in which loops can interact, in which one whole loop interacts with another whole loop, rather than a reaction in one loop affecting the performance of a reaction in the other. The homeostatic emergent property is important, just as the control property of the individual loops is the important underlying reason for the operation of protocols.

III.2.6 Loops of Loops

A protocol develops because the actions of one individual can help another to control some perception. The initiator disturbs a perception controlled by the continuer in order that the continuer's control actions should favourably affect a perception controlled by the initiator. We could call the continuer a "benefactor" and the initiator a "beneficiary". McClelland's examples illustrate deliberate perceptual control of paths 2 and 3 by creating new atenfels that another anonymous controller could use in controlling some perception.

We could add a path 4 example in the same vein: the construction of avalanche sheds that protect some roads in alpine avalanche zones. Such sheds reduce or eliminate disturbances to controlled perceptions of roads being passable, which are in turn controlled perceptions of path 3 atenfels. The controller that controls for the provision of any of these atenfels is a benefactor, though the beneficiary may not be known, or even present when the atenfels are created.

Will negative feedback loops caused by the side-effects of control be likely to exist in a population "soup" of control units? The farmer grows food, the agent buys and sells it to control his own perception of money in hand, the customer buys the food to control a hunger-satiety perception, the sales analyst notes the customer's preference and tells the farmer, the farmer changes what he grows to suit more customers, more customers buy more food, and so on around the loop. All these are side-effects. How likely is it that at least one such beneficial side-effect loop will exist in a set of N interacting individuals, each controlling independent perceptions of similar or different environmental variables?

Figure II.2.6 shows that even with a very tiny probability of 1/10,000 that any particular side-effect of A's actions will benefit B, yet if there are as few as 300 interacting people, the existence of at least one mutually beneficial loop is almost certain. If the probability that an interaction is beneficial is as high as

1/1000, the existence of at least one loop is almost certain when the population is as small as 100. And where at least one loop is almost certain, there is a high probability that several more exist.

The probabilities shown in Figure II.2.6 are worst-case values. The heavy curves assume that interactions occur at random, whereas the light curves assume that loops are actively avoided. Real networks are seldom, if ever, connected randomly, and loop-making connections are, if anything more probable than random connections. If A talks to B and B talks to C, the probability that A talks to C is much higher, not lower, than the probability that A talks to a person chosen randomly from the entire population. Accordingly, the likelihood that several loops exist in the population is actually very much higher than is shown in either panel of Figure II.2.6.

What the Figure really shows is that there is a critical group size, probably rather lower than is shown on the X axis, below which the probability that any beneficial loop exists is low, and above which the probability is high that many such loops exist. In Chapter II.2 the density of such loop connections thus marked a "phase transition" in the elemental soup that depended on the diversity of the basic elements. Now we use the same argument to argue that a sufficient diversity of roles is likely to lead to a similar phase transition, in which the structure of a society changes.

With low diversity, most people are "Jacks or Jills of all trades", but when the "trades" become too many, some people begin to specialize. Physiology enforces some specialization around the distribution of roles across genders and ages within the family, but not necessarily to the degree usually seen. And if we take entire families as units, the physiologically enforced roles are similar from family to family. The roles of interest are those for which the side-effects of control extend beyond the family group. If it takes five people to kill a buffalo, that buffalo would feed several families, and must do so if the meat is to be eaten fresh. But the same person may be at once a stone-knapper, a fisher, a tracker, a hunter, a cook, and a roofer.

If Abe makes better spear points than Boris, but Boris is a better tracker than Abe, maybe Boris gives up trying to make his own spear points and trades with Abe by helping Abe track prey that they kill together and that both families eat, along with guests. This kind of symmetry-breaking across skills becomes exaggerated the more different skills there are that prove useful to someone outside the person's family. The group has no need for a skill in making gold ornaments until someone discovers that the gold lying around can be used for ornament and someone liked it when they wore the gold. The more skills there are, the more chance the side effects of using the skills will ease someone else's control. The gold-ornament maker provides ornaments that enhance the chance that the girl will get the boy she wants, for example.

This critical group role diversity may well be at least as responsible for the transition from a nomadic to a sedentary lifestyle as was the invention of agriculture. The girl could not rely on the ornament maker being available with gold and with tools when wanted if the large group was travelling all the time to find new food sources. It is much easier if you just can go to the particular addresses in a non-moving village where the ornament-maker, the barber, the shoe-maker and other specialists work and keep their necessary tools and supplies, and where their suppliers can reliably go to deliver their goods.

Agriculture is not easy if you are a nomad, but without agriculture you tend to deplete the local food supply if you don't move around. Furthermore, the increase of controllable perceptions due to the appearance of a source of food influenced by the collective action of people must have interacted with the critical group size by increasing the possibilities for catalytic effects.

The details are not really relevant to the argument, because the same argument works given only a sufficient diversity of roles that affect other people's ability to control a diversity of perceptions. Autocatalytic loops will almost certainly come into being, and the homeostatic ones will tend to survive

longer than the ones that grow with no bounds other than limits on the supply of resources and energy — the Tragedy of the Commons (Harding, 1968). It is worth noting that the same argument can be used almost unchanged to account for punctate evolution and for inventions made "before their time".

Earlier, we talked about co-reorganization in the development of protocols, and more recently in the reduction of bad side-effects within groups. Here we consider it in the context of larger groups. If the combined side-effects of control by other members of the population makes Q have difficulty controlling some perception, Q is likely to change. So will A, B, C, and everyone else who is affected by the actions of other people. This may look like collective control, but it is not, because all the effects on Q's ability to control are side effects of A, B, and C controlling quite different perceptions. There is no "Giant Virtual Controller" influencing anything controlled by Q. We conclude, therefore, that beneficial side-effect loops are more likely to occur among ECUs that control well than among units that control poorly or that erratically change their control actions.

The phase transition from independent life in which everyone has to be a Jack or Jill of all trades to one in which the community is full of beneficial side-effect loops derived from the development of specialized roles makes life easier for everyone. The stability of this structure depends, however, on the fact that the majority of community members actually participate in the beneficial loops, and do not have to fend for themselves because they can neither benefit nor contribute (or worse, that they contribute but do not benefit, in a structure we might call "colonialism" or "income inequality" whether the disadvantaged party is a person or a larger group). We will return to this thought near the end of the book, when we discuss "Government and Revolution" and "Colonialism as an Abuse of Power".

We can use the same argument and statistical analysis to compute the effects of interactions among different mutually beneficial loops. Of course, any one person controls many perceptions. Accordingly a person can, and probably does, belong to more than one such loop. Again, however, we consider the worst case, and ignore this probability, and assume that the loops have no members in common. In other words, we treat each mutually beneficial loop as though it were a control unit in the previous calculation, and can see that when there are enough mutually beneficial loops, it becomes almost certain that some among them will be mutually beneficial as loops, though perhaps not to any particular control function within either loop. The actions of one class as a whole may ease control by the members of another class, so the statistical analysis above can be carried further, substituting numbers of loops for numbers of control units.

Loop to loop interactions are similar to the Giant Virtual Controller's control loop, in that they consist of the combined side-effects of the actions of the individual controllers that constitute each loop. But there is a difference, suggested schematically in Figure III.2.9.

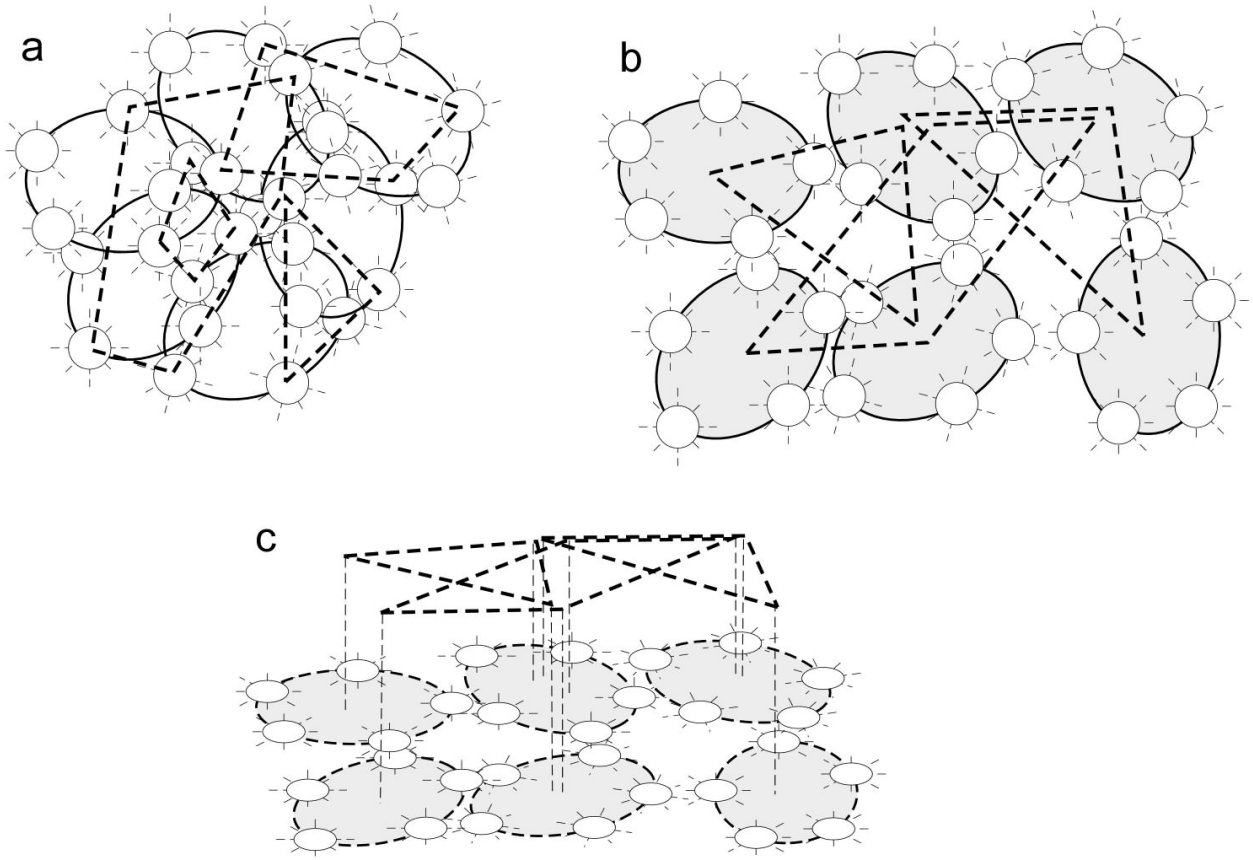


Figure III.2.9 The actions of the individual controllers in a negative feedback loop will have side-effects that affect the control abilities of controllers in other loops. These combined side-effects may also form negative feedback (beneficial) loops. The effects can be visualized in various ways: (a) showing the individual control units that are connected in beneficial loops but have side-effects on ECUs in other loops; (b) loops in which the individual control units have relatively little side-effect influence on individual ECUs in other loops, but the combined effect of the units in one loop on those of the other benefit both loops; (c) as (b) but shown as a two-level structure analogous to the HPCT control hierarchy.

In Figure III.2.9a six basic side-effect loops are shown by ovals. Some of the controllers within those loops, shown as small white circles, have side-effects that influence the control ability of controllers in other basic loops, not necessarily by the same mechanism as the beneficial mechanism in any of the basic loops. When the controller was isolated, its side effect might not have influenced the other controller as it does when it is part of a functioning and stabilizing loop, so its influence is shown as a dashed straight line. The cross-loop side effects around individual controllers may themselves form beneficial loops, but these loops depend on the continued existence of the basic loops.

Figure III.2.9b shows a slightly different case. In this case, no one controller is seen as having a particularly strong influence on any particular controller in another loop, but the total effect of the actions in one loop improve the stability of another loop, and these connections can themselves form loops. Three such loops are shown. This depiction can also be used to represent case (a), ignoring the actual controllers involved in the supported loops, and attributing the support to the loops themselves.

An example of this case might have the farmer-customer loop as one of three, a loop involving technology creators and users as another and a loop involving commuters and traffic control as a third. No one customer's food purchasing actions have side effects that significantly influence food availability, but customers as a whole do influence what wholesalers purchase and what farmers grow. The availability of food influences the creative abilities of technological innovators, and the users of technology influence which applications and hardware grow or are discarded. The availability of different technologies affects the flow of traffic and the abilities of transport companies to provide timed transfer of food from farmer to distribution centres and thence to the markets where consumers can purchase the food, as well as the ability of customers to access different food suppliers.

None of the side-effects of individual actions in these side-effect loops need have a noticeable influence on any of the other loops, but the collective side effects of each entire loop on the other loops do help the ECUs in the other loops to control better. This would not happen if the ECUs were isolated instead of being part of the assisted loop. Since better control implies a lower likelihood of change due to reorganization, the loop-to-loop side effects help the loops to survive reorganization as entities, and this is even more true if the loop-to-loop beneficial interactions form higher-level loops of loops, as suggested in Figure III.2.9c.

Figure III.2.9c shows the same case as Figure III.2.9b, but it emphasizes the concept of levels of loops and super-loops of loops. The three loops of the upper layer (two three-element loops and one four-element loop) have a relationship to the loops of the lower layer analogous to the relationship between the control units at successive levels of the Powers HPCT control hierarchy. Every individual controller shown by a small white circle in all the panels of Figure III.2.9 belongs somewhere in a Powers hierarchy, but no two of them are necessarily in the same level or even in the same hierarchy (organism).

It is natural to ask whether the same mathematics of probability that applied to the development of beneficial side-effect loops can be repeated when considering the likelihood that there will be higher-level loops of beneficial interactions of the kind suggested in Figure III.2.9. The answer is that if beneficial loops do occur among individual control systems, then second-order loops will also exist if the number of basic loops grows sufficiently. If the number of individuals required to create a phase change across which the number of loops grows from near zero to many is in the low hundreds, then, depending on how many individuals on average participate in a basic loop, the number of individuals required for a second phase change to multiple second-level loops is not likely to exceed low thousands. This is the point at which, for example, specialized roles have enough players that the players begin to form guilds for mutual support.

Since the benefits of the basic side-effect loops is achieved by the specialization of the perceptions controlled by the individuals, one might expect that the benefits of second-order loops would be achieved by specialization of the basic loops. One basic loop might involve the production of food, another the construction of houses, and yet another the production of textiles, each of which serves to ease control of various perceptions in the individuals within the separate basic loops. The basic loops become specializations within which the individuals provide more refined specialization than they would do if the basic loops were all "general-purpose", providing generalized ease of control to their members, each loop in much the same way but with different membership. The extreme of this might have been reached in Henry Ford's assembly lines in which a single worker specialized in, say, tightening the bolts on a particular component of the car.

III.2.7 Side-effect Loops in Conflict

In all of this we show the interrelations of the cross-influences between controllers as forming nice simple loops in which the side-effects of controller A benefit controller B, controller B's side-effects benefit controller C, and so forth until we arrive back at A.

But this is too simple. If there is one pathway from A back to A, there are likely to be several. If there is a Loop 1 from A to A, a Loop 2 from P back to P, and a Loop 3 from X back to X with no controllers in common among the loops, nevertheless the the side effects of controller B in Loop 1 might ease control of Q in Loop 2, which might benefit Y in Loop 3 which benefits C in Loop1, which because of its place in Loop 1 benefits B, forming a Loop 4 (B-Q-Y-C-…-B), as shown in Figure III.2.10. The whole set of interconnections will not be nice discrete loops, but a complex network, in which not everything will be beneficial.

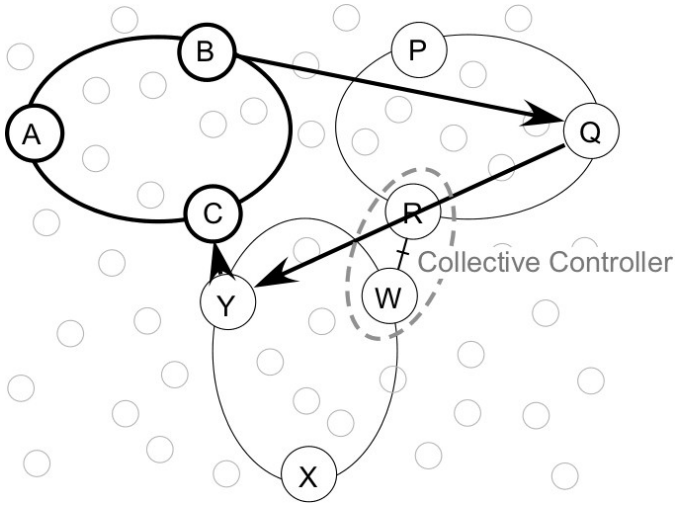


Figure III.2.10 There will be many beneficial side-effect loops involving the same controllers (shown by circles; light grey circles indicate that there are many more controllers than the ones highlighted. If there are beneficial loops ABC, PQR, and WXY, there is no reason B should not also help Q, which helps Y, which helps C, which is in a loop that contains B. When there are many such interconnections, the whole structure is more of a complex network than of a set of loops, though the concept of the negative feedback loop remains paramount. Controllers R and W are shown as being in a resource conflict, in which the resulting collective controller provides a stabilization point while R and W increase their outputs, enhancing their beneficial influences within their respective loops.

Suppose that in Figure III.2.10 the side-effects of W reduce the ability of R to control. This would reduce the negative loop gain of the PQR loop, reducing the ability of P and Q to control, but not necessarily breaking the loop. The BQYC loop would function whether or not the PQR loop was broken, but not as well as it would with a functioning PQR loop. What we see is a kind of "remote interference"; because W interferes with R, Q becomes less beneficial to Y, and all the controllers marked by letters may control a little less well. Reorganization is likely to increase all around, which might reduce the interference between W and R, and might create new beneficial loops. In any particular case, it would be very difficult to predict what might happen, but on a global scale, with millions of potential control units

involved, the tendency would normally be to reduce the interference and maintain the beneficial loops, though there could be long periods in which interference increases and decreases dynamically.

An exception occurs when there is a resource-limit conflict. If in Figure III.2.10 W and R exist in conflict (a path 1,1 loop), both trying to control perceptions of the same CEV at different reference values, then, as McClelland (1993) demonstrated, together they then form a Giant Virtual Controller, which could enhance the stability of the resource for others, while their increasing control output might actually enhance their individual beneficial side-effects around their respective loops, increasing the negative feedback gain of the loops as well as escalating the conflict.

Could the Giant Virtual Controller that stabilizes the CCEV of the conflicted pair act as a beneficial component in both loops *by virtue of the conflict*? Yes, if the conflict exists in the context of a tensegrity control structure, which we now see can exist not only with individual ECUs as its elements, but also with side-effect loops as its members. If this speculation is correct, the failure of reorganization to reduce or eliminate conflicts in psychopathology or sociopathology might have some theoretical explanation. Aspects of the environment influenced by conflict-generated GVCs could be involved in stabilizing other negative feedback loops, enabling improved control of perceptions, and thus locking the reorganization process into a local optimum.

Let us examine by way of an extremely simplified hypothetical example the way in which a CCEV stabilized by conflict might strengthen the structure of a side-effect loop.

Farmer Frank controls for getting money, with a reference level well above his current perception of how much he has. Supporting his control of his wealth perception are two control units, one controlling his perception of the quantity of each of two possible types of crop, food or biofuel. He has a fixed area of land on which he can grow crops. The proportion of his land devoted to food and to biofuel is at his choice. We recognize that he controls a perception of his income, which he does by controlling his perceptions of the quantities of the two crops, both of which have a reference value equal to the amount that could be grown if his whole acreage was devoted to that one crop. There is therefore a resource conflict between them. Figure III.2.11 places that conflict in a situation with two loops, both of which involve Farmer Frank and his conflict.

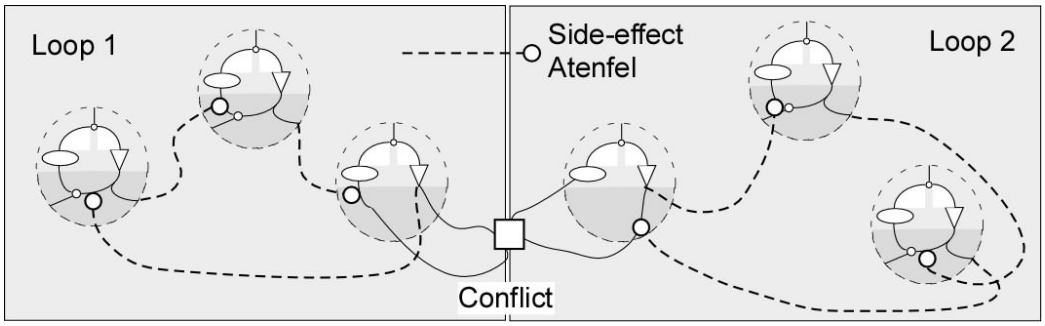


Figure III.2.11 Two loops of beneficial side-effects. In each loop one of the members has a resource conflict with a member of the other loop. The box represents the CCEV over which there is a conflict. That CCEV is stabilized by the collective control created by the conflict.

The two crops are used by different people — at least we treat in this discussion only different sets of people, even though all the people in both of the side-effect loops in our example will need food and most will need fuel. These effects must be considered in any analysis of the full network, but to make the example simpler, we treat them separately. We also simplify the situation by treating the various

individuals as individuals, though all of them could represent large numbers of people, such as all the farmers, all the grocery chains, all the gas stations, and so forth. We consider the effects of this oversimplification toward the end of the discussion.

Loop 1: Supermarket Steve runs a supermarket chain. He controls a perception of his income, which he can vary by the changing the prices at which he buys food from Farmer Frank and sells to Housewife Helen, and by varying the quantity of food on his shelves. The price of the food is determined by a "Trade and Barter" protocol with Frank, but is dictated to Helen by Steve. Variation in the quantity of food on Steve's shelves is a side-effect of Frank's control of the quantity he grows, since he sells all of it to Steve.

Helen controls for perceiving her children to be healthy and well fed. One of her supporting controlled perceptions is the quantity of food she gives them, which she must buy at Steve's supermarket. Steve controls for the amount of money that comes in from selling food, for which the amount of food on Helen's table is a side-effect.

Helen's family produces food waste as a side-effect of her control for perceiving her children to be healthy by giving them food. Farmer Frank collects the waste from Helen and composts it. He then controls for perceiving more food to be grown on any given acreage by spreading the compost over his fields. He can sell the added food to Steve if Steve has enough money to pay for it. Frank does not use compost on his biofuel crop.

Loop 2: Oily Oscar runs a gasoline refinery and controls for perceiving his income to be higher than it is, so he will sell all the gas he can refine. By law, a fixed proportion of the gas he sells must come from the biofuel crop Frank grows. How much he can sell is a side-effect of Frank's control of the quantity he grows.

Gasoline Gerald runs a gas station that gets gas from Oscar. He controls a perception of the money he can make by selling to Driver Dan. Dan is a mechanic who can fix Frank's tractor when it has a problem. Gerald's income is a side effect of Oscar's control of his own income.

Frank uses his tractor on the area devoted to biofuel, but not on the food crop area. The proper functioning of his tractor is an atenfel for his controlled perception of the amount of biofuel he grows. Dan the mechanic controls a perception of the operation of the tractor, and Frank's use of it to grow biofuel is a side-effect of Dan's control of that perception. Frank pays Dan for fixing the tractor with money he gets from Oscar's purchase of biofuel, because he keeps separate accounts for his biofuel and his food farming. Oscar gets his money only from Gerald, who gets his from Dan. All of this is abstracted in Table II.28.1.

Table II.28.1 Side-effects of control around the two loops

Loop	***Person***	***Controlled Perception***	***Atenfel***	***Side-effect***
III.1	Frank	Food Crop quantity	Compost	Food for Steve's shelves
	Steve	income	Food on shelves	Helen child well fed
	Helen	Child health	Food	Frank gets compost
III.2	Frank	Biofuel crop quantity	Operating tractor	Oscar can refine gasoline
	Oscar	Quantity of gasoline	biofuel	Gerald has gas to sell
	Gerald	income	Gas to sell	Dan's car runs

	Dan	Frank's tractor condition	Car allows Dan to get to Frank's farm	Frank can grow biofuel

Analysis: Frank controls two perceptions that are in conflict, because he has only a limited area on which to grow both crops. If he devotes more area to food, he has less on which to grow biofuel. However, the conflict is not absolute, since he can grow more food if he gets more compost and grow more biofuel if his tractor works better. If he had an unlimited area on which to grow both crops, and if he had an unlimited supply of volunteer labour, he would not need much if any compost, nor would it matter how well his tractor ran.

If Frank had an unlimited area and grew the crops just because he liked to see them grow, needing no money, he could simply give Steve all the food Steve could fit on his shelves and Oscar as much biofuel as his refinery could take. They could then control their perceptions of their incomes by what they decided to charge Helen for food and Dan for gasoline, which presumably would influence how much their customers would buy. Dan would not need much gas if Frank did not need his tractor to work well, but Helen would need to buy enough food to keep her children from starving.

Those conditions are, to say the least, unlikely. Frank has a limited area on which to grow both crops, and he has no unlimited supply of volunteer farmhands, so he needs to sell his crops to get money to buy compost and to improve the operating condition of his tractor. Frank's question is how to apportion the area devoted to each crop. He does not control a perception of the side-effects of his farming, by the very definition of side-effect. But the side-effects do alter the abilities of Steve and Oscar to control their perceptions. If Frank grows more biofuel, Oscar can produce more gasoline, but Steve would have less food on his shelves.

Steve would then have to charge more for his limited supply of food if he is to control his income perception effectively. But that implies Helen would have to pay more to control her perception of her child's health, keeping him from getting too hungry. If she did not, Frank would get less compost, and be even less able to grow food. But if Helen can and does pay more, Steve could pay Frank more for his food crop, which would allow Frank to control his income better, because he could devote a larger area to growing food, and would also get more compost so he could grow more food on his limited area.

But this would reduce the area devoted to Frank's biofuel crop, so Oscar might control his perception of the amount of biofuel he gets by offering Frank a higher price, charging Gerald a higher price for refined gasoline, which requires Dan to pay more, reducing Dan's ability to get to Frank's farm to maintain the tractor's operation unless Frank pays Dan more to buy the gas that lets him get to the farm.

The upshot of all this is that the conflict increases the outputs of all the control systems around both loops, "stiffening" the loops unless one of them breaks entirely, so that either Helen's child starves or Dan's car runs out of gas. This could happen if the escalation of output reaches some limit, allowing the other loop to win the conflict and leaving Frank to grow only one crop. Frank doesn't care either way, provided he gets the highest income he can from one crop or the other or a mixture of both, which is a higher-level controlled perception that uses either or both crops as atenfels. Everything else is side-effects, of which his control systems are unaware.

Ignoring the possibility that one of the loops breaks down, the effect of the conflict is to stabilize the CVCC of the conflict-based Giant Virtual Controller that consists of Frank's two controlled perceptions of the amount of land he devotes to his two crops. The CCEV is the proportion of Frank's land devoted to either crop. That stabilization affects the outputs of the control units all around each loop, an effect that would also occur if the gains of the control units were to increase.

A side-effect loop does not control a particular perception, but as with the Giant Virtual Controller, the participants in the side-effect loop increase their apparent and real local loop gains by virtue of

unknowingly participating in the side-effect loop. Each side-effect loop becomes stiffer because of the conflict between the two of them, in a typical tensegrity effect. We are beginning to build a loop-level tensegrity structure on top of the ECU-level tensegrity structures discussed back in Chapter 8 or the flat tensegrity structure of Section III.2.4.

The basic loops in this superficial analysis are not deliberately created by the participants. All the effects are side-effects, just as they are in the earliest stage of protocol development, but again as with a protocol, each of the effects involves the inadvertent creation of an atenfel for the next control unit in the loop. This atenfel might later become the CEV of a newly controlled perception, a condition rather more stable than the side-effect of controlling something quite different. However, we should note that in the example, the individuals would all need food, and most would need gasoline. Depending on their affluence, rising prices on either commodity could engender new resource limitation conflicts linking the example side-effect loops as well as other loops that might be related to money.

The effect of each conflict would be to create a collectively controlled CCEV, many of which, if not all, would have the effect of both creating a network of side-effect loops and of making the loops stiffer than they would be in the absence of the conflict. Some of the conflicts might result in the destruction of one of the loops, if the CCEV became controlled by the other. For example, one might not be able to afford both a car and rent, and might forgo the car, thereby reducing to zero the gain of any loops that require the side-effects of the person's use of a car.

In this section, we have treated the side-effects of a controller's action as though it affected only one other controller, a rather unrealistic proposition. Each controller's side effects might act as disturbance to several other controllers, as beneficial atenfels to some, and as creating problems with the environmental feedback loops of others. Figure III.2.11 suggested a trivial example in which all the interactions are beneficial except for one possible conflict. More realistically, the network of interactions is likely to be very complicated, and the resulting loop-level tensegrity structure to have many stiffer and looser modules, as will as some remnant "broken-rod" elements like the car-rent example, in which one loop has dominated another.

As always, however, we expect that over time, controllers suffering bad effects will tend to change by reorganization faster than those experiencing beneficial side-effects. The example of Frank's conflict suggests, however, that the stiffening that could be caused by conflict across loops might actually reduce the likelihood that some conflicts would be reorganized out of existence. The complicated loop-level tensegrity network may be strengthened by the existence of collectively controlled stabilities, in the same way as bronze is harder and less malleable than pure copper because the foreign atoms of tin or arsenic lock the surrounding planes of copper atoms from sliding against one another under small stresses.

III.2.8 Many people performing the same role

The names in our example are applied to single individuals, but they should be considered not just as representative of generic classes or roles, but as representing a large number of individuals of a class. Many different "Helens" may perform the "food buyer" role at markets run by many different Steves, and many different gas stations run by their different "Geralds" get their fuel from many different refineries run by different "Oscars". The combination of many into a representative individual is analogous to the way Powers combined the neural spikes of all the neurons in a bundle and called the result a "neural current" to make the calculations tractable. But the result may be misleading.

If all the individuals we have given a particular name did the same thing at the same moment, the difference between one and many would be uninteresting, but we cannot assume that all the Helens would

have the same price sensitivity for their food, and that all the Geralds would need more gas at the same time, and so forth. This variation affects the results.

Imagine, for example, that there was only one Helen, and our single Helen decided she could no longer afford to buy Steve's food, so she started to grow her own. Steve would not be able to pay Frank for his food crop, and Helen would not supply Frank with compost because she would use it herself. The "food" side-effect loop would be completely broken by this one change of control action by one person. The situation is different when there are many Helens, Franks, and Steves. One Helen may begin to grow her own food, but this only slightly reduces the side-effect loop gain of collective control if she is one of many hundred. Properties that are all-or-none in the case of individual side-effect loops become graded when we extend the analysis to many similar but not identical individuals, as was shown in Figure III.1.9.

Another caveat must be noted. The names represent single control units within each person, not whole people. Single control units are unable to perceive anything other than the perception they control. In particular, they do not perceive anything about their side-effects. But other units in the same person might, in which case the person might actually control a perception of the side-effect. Gerald might perceive that selling gas to Dan allowed Dan to drive to work on Frank's tractor, for example, and Gerald (controlling a different perception) might want to get food from Steve. The set of interactions of controlled perceptions quickly turns into a complex network or tensegrity structure involving side-effects, hypernodes, direct control, and protocols. Such a network is beyond the scope of this part of the book, but we will explore aspects of it in different places as we progress, starting with the simplifying effects of fractal modularity.

***III.2.9 The Octopus and the Fungus: Distributed Minds?

To this point in the Chapter and in the book as a whole, we have been tacitly assuming that perceptual control is built upon a cross-linked tree-structured "hierarchy" of perceptual control loops. Now we address problems that seem to be posed by two very different kinds of organisms that both seem to have distributed versions of perceptual control, the octopus and a fungus. Whereas we have two legs and two arms, each of which has movements limited by the internal skeleton and its attached muscles, the octopus has eight arms that have no internal skeleton and can coil and hold objects either independently or well coordinated in various groups.

The fungus, a slime-mold called *Physarum polycephalum* is even less like a vertebrate. Not only does it lack a distinctive set of body parts, but although it may grow very large, it has only one cell, a cell that has many nuclei, and that grows by adding more partitions, each of which contains a single nucleus. Despite these differences, both the octopus and the fungus give the appearance, to an external observer, of controlling a variety of perceptions. How their perceptual control system might be structured to do this is necessarily different from how a mammal or a normal single-celled bacterium might be structured to control its perceptions. In particular, the control systems of *Physarum polycephalum* must be distributed widely through its single cell's repeated nucleii, while maintaining the variety of controllable perceptual categories that it displays to the experimenter.

There are many species of octopus, each of them with the same distinguishing feature, that its eight tentacles each seem to have many of the characteristics of an elephant's trunk, with the additional capability of individually or collectively using suckers along their length to temporarily attach themselves to a surface. That surface might be prey or something over which the octopus might move. In the laboratory, researchers have difficulty in constraining an octopus to an aquarium tank, as it can climb up the glass wall and escape over it with apparent ease. Some, perhaps all, give a strong appearance of intelligence, if one defines intelligence as the solving of problems never before encountered.

Physarum polycephalum is a yellow single-celled organism with some remarkable abilities, that drew my interest when it was featured in a PBS documentary in the series "NOVA" (Season 47, Episode 12). Although single-celled, and therefore without specialized sensory organs, it has remarkable properties and abilities, among which are an ability to maintain a rhythm that is produced by an outside agency, an ability to perform efficient searches, and an ability to sense variations in ambient lighting intensity and colour (***Refs***). Although single-celled, the cell contains distinct partitions, each of which contains a nucleus as though it were a separate cell. The fungus grows by adding additional partitions, perhaps onto the growing tip of an "arm", perhaps on the side of an "arm" to start a new "arm", so that the single cell can branch into different pathways simultaneously.

Why should I combine discussion of two such different kinds of life as an octopus and slime mold? Because each seems to require that what the experimenter sees as an organism controlling some testable perception, in neither case does this controlled perception necessarily exist anywhere but as distributed. It is a virtual perception, and the controller is likewise distributed, as a "Giant Virtual Controller" (GVC, Section III.1.5). To say this, however, is to evade the issue rather than to resolve it.

The problem of the octopus in PCT is only a surface problem. Functionally, the body of an octopus, the coordinated grasping behaviour of its various arms, and its apparent ability to do two things at once, for example using some of its arms to hold on to some fixed object while using others to pull on something else is no more mysterious than is the ability of a tennis player to run and hit the ball while running. The tennis player controls a perception of the ball leaving her racquet in a desired direction, while the octopus presumably controls a similar perception, such as perceiving itself out of the tank, and as the athlete must control perceptions of the tensions in the fibres of many well separated muscles in coordination, and do those controls locally, so one can imagine that the octopus controls at some level perceptions of grasping, perceptions (within the arm) of coiling, and perceptions of tensions in muscle fibres, of which many are executed in the arms, and only the higher levels are in the head.

I think we can leave the apparently strange, but ultimately familiar octopus at this point. But what about the fungus? It has no central point, other than in the sense that network centrality concepts might be used. Even if we were to say that this partition is more central than that one, nothing about the flow of fluid among the arms seems to suggest an informational cyclic flow that would allow the kind of apparent control exhibited by the fungus as a whole in the growth and death patterns of its arms.

Chapter III.3. The Fractal Community

We will soon return to Sophie and Len's family of "syncon-speakers" who we met in Chapter 1. A few generations will have passed and the family will have grown. The various family members interact with each other, some closely, some only occasionally and some pairs of distant cousins never meet. They may live in different kinds of environments, so their interactions use protocols of different kinds for different purposes. A city dweller may have a set of protocols for different kinds of trade, none of which are ever used by a hunter-gatherer in the jungle, though both might be members of the same extended family.

Whatever the purpose, however, the underlying structure of every protocol is the same, though its precise form, the norms of its execution, will vary according to the cultural circumstances and the complexity of the Primal Message.

III.3.1 Collective Control of Protocol Form

The form of a protocol is potentially observable, even sometimes by a non-participant. If one party has a controlled perception (perhaps at the sequence level of the Powers hierarchy) of how the protocol should be performed, sufficiently large deviations from correct performance will result in an error to be corrected. The form of the protocol can be a CEV, even though it is intangible.

If it can be a CEV, it can be a CCEV. The potential users of the protocol might well come into conflict over it if they have different references for "proper form", and so long as they sustain that conflict, their use of the protocol in question will not be very effective. Indeed, in the absence of reorganization, the conflict could escalate essentially without limit — as sometimes happens for rituals when groups go to war simply because they differ on the actions that indicate proper religious observance. According to our earlier discussion, the initially conflicted protocol users presumably would by reorganization eventually come to a common reference value for the protocol form when the protocol doesn't work. But there is another way of coming to an agreement that might well take precedence.

It is reasonable to suppose that the potential users of a protocol also control perceptions of their own level of cooperation, with reference values to see themselves (and to be seen by others) as cooperating (or not). These perceptions will be in error if the potential partners are in conflict over the protocol form, so if they want to collaborate rather than fight, they must control for bringing their subordinate reference values into near coincidence. Rather than trying out actions that do not work, they might, for example, ask each other "How do you want to do this", before actually attempting to use a protocol they had not previously used either together or with others playing similar roles.

This level of perceptual control can be seen as controlling for perceiving themselves (and being perceived) to be members of a group, a group defined by the ability to use that particular protocol. The protocol, and other protocols used by the same two people in other circumstances, bind them into a social dyad that we might call "friends".

It is not strictly necessary for the friends to have exactly the same references for the protocol form, provided that the two references are within each other's tolerance bounds. No conflict will occur in this case, though the form used by one party may differ in detail from the form used by the other. So long as the protocol works properly, no changes are to be expected. However, the form, as a CCEV, might drift over time as the partners slightly vary their use of the protocol, remaining within each other's tolerance zone. So long as the partners are controlling perceptions of each other as "friend" the drift may appear to an outside observer to be significant, whereas to the parties involved, it is just their way of doing things. When we deal with cultural and linguistic forms in whole communities, such drifts become interesting.

III.3.2 Tensegrity and Modular organization

As an organism matures, it develops ever more elementary control Units (ECUs) at an increasing number of hierarchic levels to control perceptions of different kinds and complexity. Within the organism, these ECUs form a complicated structure, which, until evidence suggests otherwise, we assume to be the hierarchy proposed by Powers augmented by the lateral connections described in Chapter 9, the whole creating a complex that is analogous to a resilient and flexible tensegrity structure composed of smaller (lower hierarchic level) tensegrity structures that take the roles of its rods and wires.

Whatever the structure, if the ECUs within an organism were to operate strictly as independent agents, they would often be in conflict with each other, because an organism usually has, by several orders of magnitude, fewer and slower means of acting on the environment than it has for perceiving variations in the environment. Is this true also of ECUs in different bodies? That depends on the degree of overlap in the environments within which they control their perceptions. The more overlap there is, the greater the likelihood of conflict.

Each body has more or less the same number of means of acting on the environment. If they were independent, their effects on the environment would be combined quite simply, perhaps additively. But are they likely to be independent? If they have effects that influence each others' CEVs, they are not, as we discussed in our discussions of the initiation of protocols. New feedback loops may be created, some with positive feedback, which can lead to dangerous conflict, and some with negative feedback — homeostatic loops. In the case of what the Analyst would see as conflict, it is quite possible that neither person perceives the source of the problem. They may simply perceive that something they are trying to control is becoming increasingly more difficult to control.

ECUs in conflict do not control their perceptions very well, in that they cannot move their CEVs toward their references because of the countervailing influence of one or more other control units. If they don't control well, they are unlikely to have consistent effects on the intrinsic variables on which the organism's life depends. Consequently, their internal structure is likely to reorganize in the direction of reducing the likelihood of conflict.

Conflicts can be reduced in several ways. The manner of controlling conflicted perceptions may change so that two initially conflicting control loops in different bodies begin to move apart spatially or perceptually so that the overlap between their environments shrinks, they may no longer try to use the same atenfels while sharing the same environment, perceptual functions may change, perceptions may even cease to be controlled when control ceases to be effective[8]. The net result is that the set of ECUs reorganizes into an ecology in which the effects of control are often mutually supportive, but may also contain residual conflicts that become overt on occasion (Section III.2.7).

In "Perceptual Complexes" (Section 5.3) we used the example of the control of chair property perceptions as opposed to chair-part property perceptions to show how structural regularities in the environment can allow reductions in conflict, provided that new higher-level perceptual functions are developed to create perceptual signals that take these regularities into account. If lower-level perceptions correspond to different properties of an environmental structure that vary in ways that constrain their inter-relations, reorganization can create the necessary higher-level perceptions of those structures.

Control of the higher-level "structural" perceptions can then reduce conflict by ensuring that the reference values supplied to the lower-level control units covary according to the constraints of the

8. Think voter apathy in North America, where the voters' votes seldom have any apparent influence in helping most of them to control their perceptions. "Politicians are all the same, all promises and no action except to enrich themselves and their friends, so why bother to vote?"

structured part of the environment. The control degrees of freedom are greatly reduced thereby, which is one way of enlarging the reference macrostate for control, making control easier overall by reducing the number of individual perceptions to be controlled. Likewise, the reference values for the lower-level perceptions are constrained to change together according to the way that the environment has guided reorganization, setting up some "rods" of a lower-level tensegrity control structure.

It is important to note that although we can never know whether what we perceive is close to what is really "out there", nevertheless the constraints that guide reorganization into creating controlled "whole chair" perceptions are constraints in the unknowable real world, whether those constraints are imposed by real chairs or by some super-entity manipulating our perceptions (Chapter 10). The constraints that apply are not constraints we perceive or imagine. They are real, even though the corresponding perceptions may be illusory.

In the introductory discussion of controlling "chair" perceptions rather than "chair-part" perceptions (Section 5.3), we ignored the likelihood that there could be other chairs in the same room, or that there might be tables and other furniture. Perceptions of each of these other structures can be controlled, almost but not quite independently of perceptions of the first chair. The reference macrostate for the two chairs cannot, for example, have them both occupying the same space. If the two reference locations were the same, the perceptual controls would be in conflict.

This is almost the inverse of McClelland's conflictive control, in which two controllers try to make a single CEV take on two different values. Here we have two controllers trying to make two different CEVs take on the same value, something that is possible in principle but not in practice, because of the physical properties of the two objects whose locations are the CEVs in question. A chair and a cloud of smoke, or two marching groups of soldiers on parade can be co-located because a chair can move through smoke, and one marching squad of soldiers can be co-located with another, even if the individual soldiers cannot. But one chair cannot move through another chair.

The chairs and table may have other constraints on their joint control, constraints implicit in the reference values coming from yet higher levels. Why are the table and chairs in this room? Perhaps it is because someone is controlling for a number of of invited guests to eat meals there. Are there enough chairs for the guests? In imagination the host seats the guests on the chairs, with a reference that there be no empty chair and no unseated guest. The number of guests provides another constraint on perceptual controls for acquiring and placing chairs. The chairs must be located in a specific orientation with respect to the table and each other, and within a certain range of distances from the table and each other.

In our minimal 3-D control analogues to a minimal 3-D physical tensegrity structure, the "rod" elements of the structure are provided by the constraints on the relative values of the references supplied by the structures perceived at the next higher level. The next higher level has reorganized to provide these references only because the environment causes conflicts at the lower levels when the references supplied to it fail to allow for environmental constraints.

The "dining room arrangement" appears different on the surface. It is a social structure, different in different cultures, but in any one culture it serves to restrict the reference macrostate for locations and orientations of the dining room furniture just as much as do the physical properties of the individual objects. The constraints from higher levels complement those from the environment much as do complementary rods in a physical tensegrity structure.

Social structures can be strongly controlled collectively. In a "dining room arrangement" of two chairs at one small table, in some cultures the chairs should, by collective control, be on opposite sides of the table, while in other cultures the chairs should be at adjacent sides. When the chairs are moved around the table, moving only one will result in error for the perception of the placement of the other, just as moving

one end of a rod in a physical tensegrity structure usually means that the other end of the rod will move. The constraint defines one boundary of the reference macrostructure that will be effective at the lower level.

All of these constraints have tolerances, except probably for matching the numbers of chairs and guests, but those tolerances are limited, and the tensegrity "rods", though perhaps somewhat "compressible", nevertheless cannot be compressed without limit. They can, however, sometimes be stretched, in contrast to the fixed lengths of physical metal rods. If there is plenty of room around the table for the expected number of guests, the chairs can be placed close together in a cluster or distributed with some space around them. The degree of stretch and compression of the "rods" is a measure of the tolerance zones of the higher-level perceptions, or, looked at in another way, the sizes of the reference macrostates.

Just as we hypothesized nested tensegrity structures forming somewhat compressible "rods" within an individual hierarchy, so we also expect to find similar tensegrity components within any ecology of ECUs, no matter how many individuals they reside in. The reference values that are the ends of the "rods" may be derived from outputs of higher-level ECUs, induced by physical constraints, caused by actual conflict, or in social systems very commonly created by the high-gain controlling of a Giant Virtual Controller. The tensegrity "wires" are the approach controllers internal to the organisms — anywhere from bacterial to human — that constitute the ecology. Giant Virtual Controllers "pull" many such "wires", but they also may "push" as avoidance controllers that, for example, create cultural taboos.

Such a social or individual ecology is likely to be modular, with small groups of ECUs at any level of the Powers hierarchy interacting conflict-free or nearly so more strongly within their module than between modules. The modules correspond to perceived structures, whether or not those structures can be described in physical terms. How a particular culture of English aristocrats arrange to sit for dinner does not influence and is not influenced by how it is properly done in polite Japanese society.

The structure often shown in diagrams of the HPCT hierarchy is not modular, in that every low-level ECU is shown as connecting with any and every ECU at the next level up and down. However, as suggested when we discussed the perception of the "chair" location and orientation in Section 5.3, the higher-level ECUs are likely to be constructed because of coherences in the real environment. Only low-level perceptions relating to the chair parts would be connected to the "chair-orientation" and "chair-location" ECUs. Perceptions relating to the other objects in the room would vary with the person's viewpoint on the chair and the chair's physical location in the room. Perceptions of aspects of the environment that vary independently of the chair location and orientation would not be associated consistently with them, at least not at levels distinguishable from the ambient noise that assists reorganization[9].

Module boundaries are likely to be fuzzy. "Chair-leg-location" may well interact with "own-foot-location" perception to control for their separation to be greater than zero, thus avoiding a stubbed toe. "Own-foot-location" perception probably interacts with some perceptions of the walking surface to allow control of walking on irregular ground. And so forth; although some higher-level perceptions may have contributions only from a limited set of lower-level ones, those same lower-level perceptions may well contribute to many quite distinct higher-level ones.

What is probably true of control systems reorganizing within an individual is observably true of the interactions among individuals. Considered all together within a module such as a family or a club, they allow all the individuals to control more of their perceptions and to control better than they would without

9. In this connection one should not discount the easy development of superstitions and patterns seen in noise, such as whispered voices heard in the sound of an air vent.

the co-reorganization, just as within an individual the ECUs reorganize what and how they control so that they control better by restricting the range of what they influence. Small groups such as families, sports teams, boards of directors, and the like interact more closely (in the appropriate context) within the group than they do with people outside the group, avoiding conflict by taking on different roles.

When sets of ECUs reorganize in a specific context to take advantage of the presence of other people, the within-group interactions are likely to form protocols that are more stable and resilient than can be constructed by reorganization through the more widely varied interactions outside the group context. Families develop protocols used only with family members in family-specific contexts, sports teams develop protocols used only within the team while playing the sport, and so forth. Any such module, in which a set of protocols has reorganized by repeated interactions within the same group of people, can be called "a culture".

Conflict reduction in a human society, and perhaps some non-human ones, is enhanced by the co-reorganization that leads to the construction of protocols. Protocols allow the participants to help one another, in the way different dolphin groups have developed different cooperative fishing techniques to suit learned from their local pod, or chimpanzees use different tools and technologies special to their own family group to acquire different kinds of food. Perhaps more importantly, protocols allow human participants to discover something about each others' World Models. Perceptions of how others perceive the world are part of each individual's perceptual state, and thus affect how the individuals can effectively act to control that perceptual state.

Just as any low-level ECU can be part of the feedback loop of several higher-level ECUs, so the partners in small modules such as siblings or a nuclear family also are part of several larger modules such as their sports friends and their religious communities. In this sense, the culture of a small group such as a family is part of the culture of a larger group to which the family or its individual members belong. We talk of the "English rugby club culture" just as we do for the larger module "the North Atlantic English-speaking culture". The smaller group can use all of the protocols of the larger group if need be, but some of them might well be superseded by protocols for the same purpose special to the small group.

When interacting with partners in these larger groups, small-group protocols will not always work properly. For example, a particular pair of friends may use mild insults as a way of allowing each to perceive the other's goodwill, whereas the same language used to a random member of the larger group might lead him to perceive the opposite. On one occasion I visited an establishment in a foreign country, where a close friend with whom I had a scientific disagreement was on Sabbatical. A local senior researcher, a friend to both of us, overheard our arguments about a fundamental aspect of my friend's research, and afterwards commented that he did not see how we could remain friends after such a fierce quarrel. Yet both of us had much enjoyed the interchange. I would not have used the same kind of approach in discussing the foreign researcher's work, even though he, too, was a long-time friend with whom I had worked closely!

III.3.3 Individuals and Roles

At the level of individual perceptual control, a name for the modules of protocol usage might be "sets of complementary roles". A person plays a variety of roles in different modules, each of which complements roles played by other members of the same module. At the extreme, in a particular protocol such as "Give me X" used by Len with Rob, the continuer, Rob, plays the role of "giver", and Len the role of "hopeful receiver". Sets of such roles may tend to relate to one another to create what we have defined as a "structure".

Structures, as we have seen, are small macrostates within a larger universe of possibilities. Many structures that are roles can be given labels such as “mother”, “ice-cream seller”, or “scientist”. An individual could play all of these roles, but not within the same module. She would be a mother in the family module, a scientist in a research laboratory module, and an ice-cream seller at times when not working at the office (the time constraint providing a tensegrity “rod” in a higher-level tensegrity structure of compatible and incompatible roles).

A few possible relationships that determine roles are shown in Figure III.3.1. The star represents a person, while the distance from a phrase or word to the star represents the relative frequency of interactions between that person and any particular person in the group mentioned, more distance meaning fewer interactions. The relations are, for the most part, reciprocal. If the “Star” person is an “Old Friend” to Zach, then Zach is probably an “Old Friend” to the Star person. If Judy is a “Teacher” of the Star person, then the Star person is a “Student” of Judy. The more distant the group, the larger and looser the modules within which those individuals or roles might interact, and the less likely it is that the Star person will perceive a player of a role as a person rather than as a role.

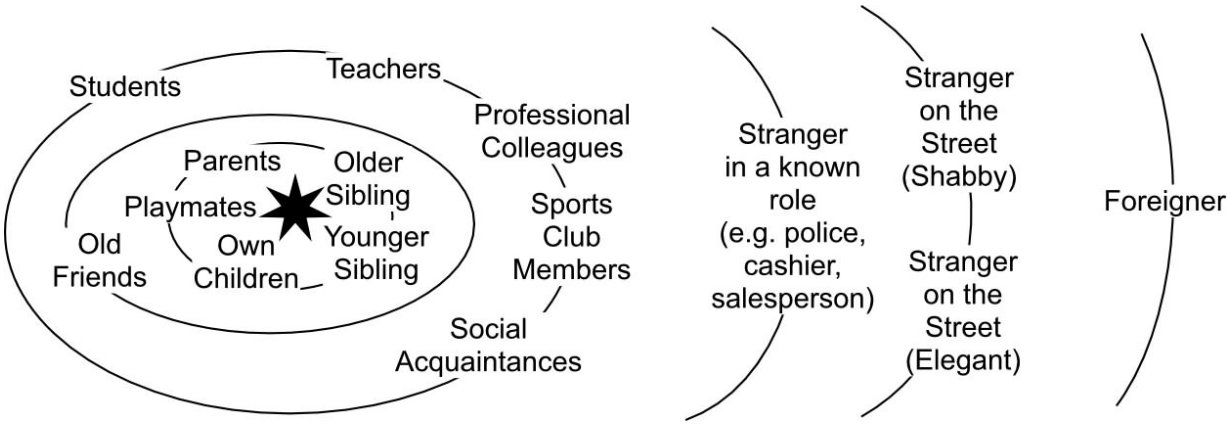


Figure III.3.1. Schematic of distances between a person and others who have various roles relative to the person. More distance implies less frequent interactions with any particular member of the listed group, and hence a less well-developed person-specific protocol structure.

Fewer interactions with an individual in a distant group mean fewer opportunities to develop protocols useful for interactions with that specific individual. However, since many different individuals belong to most of the distant groups, it is quite possible that the central person (who we can call Jake) has more interactions with “salespersons” than with any individual salesperson (Susan, Gary, Penelope, John, etc.). The salesperson (Susan) likewise has many more interactions with “Customers” (Jake, Simon, Deanna, Gaby, etc.) than the person Susan does with the person Jake. Considered together, there are likely to be many orders of magnitude more interactions between “Salesperson” and “Customer” than between Susan and Jake.

A salesperson (a role) in a store is likely to perform a greeting protocol with a customer (another role) quite differently from the way the same salesperson (Arthur) would execute a greeting with his friend Trevor, even if Trevor happened at that moment to be playing the role of customer. The customer of the mother who is an ice-cream seller might meet a different person selling the ice-cream the next time he wants one, but the protocol that gets him a vanilla-chocolate cone is the same because the role is the same.

Figure III.3.2 suggests the numbers of different individuals who might fall into different categories in relation to a central person. The more people in a category, the more likely it is that one will use role-

specific protocols with them rather than individualized protocols. Role-specific protocol forms are likely to be more rigidly controlled collectively than are protocols used with specific people, because there are fewer different things one can expect a "role" to do for you than you might expect of a family member or close friend. A "Salesperson" may be expected to "sell" while you "buy", and perhaps to "inform" when you "Ask for Directions", but not to "Teach Family History" or "Share A Picnic", though you might use either of the latter with sister Julie, who happens to be a salesperson. When Julie is playing the role of salesperson and you the role of customer, Julie will not be using a "Teach Family History" kind of protocol.

Within the acceptable protocols, also, the range of language used is likely to be less variable in an interaction between roles than in an interaction between individuals. We should expect "role-protocols" to have smaller reference macrostates for their forms than would "person-protocols".

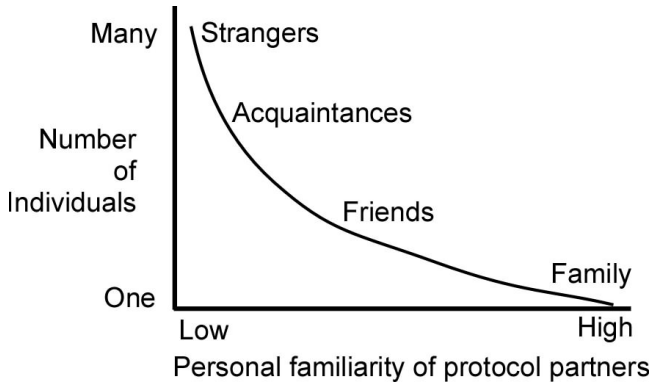


Figure III.2.2 One must use generic protocols when partnered with an arbitrary one of many people who might play a particular role, but is more likely to use idiosyncratic versions of the same protocol when dealing with family or close friends.

How can someone encountering an unknown individual perceive what role, if any, is being played by that individual? In many cases a role is labelled with a uniform just as precisely as it could be labelled by a word. In the military, the "role as uniform" principle is carried to an extreme. The uniform identifies not only that the individual is a member of, say, the Army, but also the individual's rank, speciality, and to some extent competence and experience in the form of medal ribbons. It is sometimes said that a soldier salutes the uniform, not the person inside the uniform. The uniform of a beach lifeguard differs from the clothing worn by the swimmers and sunbathers they protect; the uniform of a business executive differs from that of a hotel doorman.

Besides uniforms, roles can be identified by associated material objects or places. A taxi-driver arrives driving a taxi, a cashier stands behind a counter, a bride wears a dress she would be unlikely to wear on any other occasion. Indeed, according to Miller (2016), the archaeologist Fiona Coward suggests that the acquisition of material goods enabled the development of settled societies:

> *... at many sites ... rich material culture preceded the growth of settlements. If so, material culture may have enabled larger communities rather than merely being a byproduct of them. The growing diversity of tools, jewelry, and figurines helped delineate social roles, Coward says. (Miller, 2016, p910).*

"… the dramatic scaling-up of social lives apparent among these early Neolithic groups presented significant problems of its own. Not only ecological but cognitive constraints needed to be overcome before long-term aggregations could be established. Some of the innovative practices […] include an increasing elaboration of material culture environments to simplify social interactions with the increasing proportion of the population that individuals do not know very well, and the establishment of additional new types of formalized, 'top-down' social organization and group and religious beliefs to minimize the costs of 'policing' communities and identifying free riders. (Coward and Dunbar, 2014)

This is the same point that we argued in Section II.2.4, except that in Section II.2.4 we postulated that the causality is not in the direction argued by these authors, but is instead the result of the essential creativeness of homeostatic loops. The stability of these loops both requires and produces an increasing variety of both material and conceptual products, and in the absence of technologically supported communication also requires stability of place. It is not unreasonable, however, to suggest that variety and specialization of skills may have facilitated the growth of settlements at the same time as the reverse was happening.

How could an individual reorganize to construct protocols that work properly with "roles" as opposed to individuals? After all, if one lives in a major city, when playing the role of "customer" one might meet a particular salesperson only once in a lifetime. The roles "Salesperson" and "Customer" have no ECUs to reorganize in the way "this salesperson" and "that customer" might. When we discussed the interactions between Rob and Len, Len and Sophie, or Len and Sophie with Dan, the interactions that allowed the complementary reorganizations of Initiating and Continuing parts of a protocol happened within the control hierarchies of the specific interacting individuals. That is not the case when an individual interacts with a collection of different people playing a given "role".

To illustrate how reorganization might work with roles rather than individuals performing a protocol, we extend Len and Sophie's family, initially only slightly by adding Jack and Jill, two siblings for Dan. Soon, we will add more generations and separated branches of the family.

III.3.4 Extending Len and Sophie's family

Jack and Jill, like their brother Dan, have learned by reorganizing in the way we discussed in Chapter 1 during interactions with Len and Sophie how to initiate protocols. They are now able to control a variety of perceptions by disturbing Len or Sophie's controlled perceptions in such a way that the control actions of the parent reduce error in the child's controlled perception. In practice, they would also have been likely to reorganize continuation protocols similarly, but here we assume that they did not, and investigate another way in which protocol continuations might come into existence.

Let us suppose that Dan initiates a protocol such as "Give me X" with Jill, who has learned only the initiating half of the protocol from interactions with Sophie and Len. She, like Dan, expects to be given things, but has not learned also to give. When Dan initiates "Give me X", Jill does not act to reduce the error in Dan's perception of his possession of X.

What might happen next? Perhaps Dan's protocol initiation did not disturb any perception Jill controls. Perhaps it did disturb a perception she controls, but she has not yet reorganized to control that perception by the actions Dan needs if his perception is to be brought nearer its reference. How does Dan get X from Jill, and how does Jill learn to complete the protocol so that the interaction will work smoothly in future?

As aforementioned, one of the mantras of PCT is "many means to the same end". To Dan, what matters is control of the perception that would be performed if Jill properly executed the continuing side of the protocol pair and gave him X. Since she doesn't, either Dan will cease trying to control that perception or he will vary his actions until he achieves a useful result.

Maybe he just grabs "X" from Jill, but we assume he does not. Whatever he does, so long as his controlled perception can be influenced only by Jill's action, his own action must disturb some perception Jill controls. Since, if Dan persists, one or other of Jill's perceptions will continue to be in error until she provides X, she will probably reorganize until she produces an output that reduces the error in Dan's initiating perception (or that dissuades him from continuing to try to get X from her). Sibling rivalry continues during their mutual reorganization.

If both partners simultaneously vary their outputs, Dan may be changing what perception in Jill he disturbs, or he may be disturbing the same perception in Jill by varying means (just as one can vary the perception of A+B by varying either A or B or both). When Dan has reorganized to produce an output that results in his controlled perception being brought into a satisfactorily low error state (having received X from Jill), Jill has by definition executed the continuing half of a protocol. The initiating half of the protocol might not be executed in the same way Dan would do it to get X when interacting with Sophie, but it would have the same effect. Exaggerating only slightly, it would be as though he had learned to say to Sophie "Please give me the ball" but discovered that saying to Jill "*Valkay eyasko zammi*" produced the same result, a ball in hand.

Since we presumed that Jill, like Dan, had reorganized her initiating (and some continuing) protocols in interactions with Len and Sophie, she would have been able to perceive the pattern of her own outputs and of Sophie's or Len's outputs when they performed various protocols. As we discussed in Len's first interactions with Rob, the existence of relatively frequent patterns in a sparsely occupied space is likely to lead to the perception of the patterns as units in themselves, and to allow for their perceptual completion when partial patterns are sensed.

In the case of a protocol, the perception of the initiating half of a protocol might in itself lead Jill to perceive the complete protocol pattern, initially malformed because of the missing continuation. She would experience error in a control system that controlled for perceiving a well-formed protocol execution. This error would be eliminated by acting out the missing half — in other words, controlling her perceptions of her own actions with reference values corresponding to what she had observed others do in this protocol, rather than controlling a perception of the protocol form itself.

Jill's situation would be analogous to that of a tourist in a foreign land using a guidebook to say the right thing without yet understanding enough of the language and culture to be able to say it unaided. After more time in that land, the tourist becomes less dependent on the guidebook and more able to feel intuitively what to say. Likewise, Jill having had the error in her disturbed perception reduced by acting out the missing part of the protocol pattern, the actions would be likely to be retained in further reorganization around control of that perception. In other words, she would become able to use the protocol both as initiator and as continuer.

We now have two possibilities for what happens when Dan initiates a protocol with Jill for which she has developed the initiating half through interactions with Len and Sophie. Either Dan and Jill will recreate the same protocol they both used with a parent, or they will develop a modified protocol that has the same effect for Dan, controlling a particular perception, but that to an outside observer looks different, and might even truly be different in that Dan will be disturbing a different kind of perception in Jill than he would disturb in Sophie to get the same result.

If Dan and Jill have developed a new private protocol that serves the same purpose for the initiator as did the original, Jack may learn it when interacting with either of them, but all three will still use the old protocol when interacting with Len or Sophie, who have not reorganized to use the new protocol. The siblings might tend to use the new protocol amongst themselves, but the old one when talking to their parents, in a mild version of bilingualism.

Either way, one protocol version might be used when the partner is "sibling", and a different version when the partner is "parent". Quite probably, the versions would come to be used in contexts that differ not only in who is interacting with whom, but also in the type of content used in the protocol frame — one kind of "X" in one of the "Give me X" protocol forms, a different kind of "X" in the other form.

We have here a possible example of three linguistic observations: the development of teen slang, the origin of an honorific component of language, such as is prominent in Korean or Japanese (e.g., Taylor and Taylor, 1995/2014), and the development of classifiers such as "two head of cattle". If you lived in a country such as Korea or Japan, and used a formula such as "Please …" to show respect without considering the relationship to you of the person you are addressing, you might not get the kind of result you would expect in a polite North Atlantic culture. In Korean, at least as spoken in South Korea, for example:

> *Every Korean sentence, by its choice of words and verb or adjective endings, indicates whether it is addressed to a superior, equal, or inferior. The following two sentences show how the same content, "(Please) eat [the] rice," is spoken quite differently, depending on the social position of the addressee.*
>
> *To a superior:* chinji chapsuseyo.
> *To an equal or inferior:* pap mŏgŏ.
>
> *The elaborate levels and styles of Korean speech vary according to the relation among the person talked about, the listener, and the speaker. The factors considered are age, social position, familiarity, and gender. There are two basic levels: a polite level for superiors and a plain level for inferiors or equals; each of the two levels is further distinguished between formal and informal styles.*
>
> *...*
>
> *A foreigner learning Korean may find all these speech levels and styles complicated and confusing. One English-speaking professor of Korean history considers them to be the most difficult aspect of mastering the Korean language. It is reasonably safe to stick to polite speech in speaking to adults and plain speech in speaking to children. Polite speech used to children will make them giggle, while plain speech used to adults will upset them. (Taylor and Taylor, 1995/2014, Chapter 9 in the 2014 edition).*

III.3.5 Marcel: a stranger among the Js

We move on in time. Len and Sophie's family has grown through several generations and has split into small separated family clusters that have dispersed around the world and whose members seldom interact outside their own group. John, James, Jane, Jay, Jeanette, Jeremy and Joan all belong to one group, perhaps descendants of Jill. The "J" group meet and talk to each other regularly, and therefore possess perceptual functions that produce outputs when one or the other produces syncon patterns that have

evolved within their group as either a component in a protocol frame or as a content element. In other words, John perceives what Jay is controlling for when Jay uses the "Give me X" protocol and X is what John perceives to be a "BA" syncon sequence representing a spherical object that John could provide. If John is controlling for reducing error in Jay's controlled perceptions (making Jay happier), John will complete the protocol be giving Jay the ball, or will continue it by using a supporting protocol that asks Jay which spherical object he wants.

Into this group comes the wandering minstrel Marcel, who grew up in a distant group along with Mark, Maria, Malcolm, Martine and Molly, who are also descended from the long-forgotten Len and Sophie. To John, Jay, and the rest, Marcel "talks funny" and does odd things. What might happen if Marcel produced a syncon sequence that John hears as something like a mispronounced "Don mi VA"?

What happens probably depends on the situational context. The fact of hearing Marcel's synx trajectory might allow John to perceive that Marcel is trying to initiate a protocol, by trying to let John perceive what perception Marcel is trying to control through John's actions. But John cannot perceive what Marcel wants him to perceive, because Marcel's synx trajectory does not match sufficiently well any trajectory for which John has a recognizer. Nor are Marcel's apparent syncon targets located in feature space near the target locations John is accustomed to hearing from members of the "J" clan.

John, who is controlling for perceiving himself as helpful, has a problem. He perceives that he is not being helpful and has no atenfel that would allow him to be helpful. So, in the sprit of reorganization, he tries different actions, just as the new mother tries things to stop her baby's crying. Marcel also has a problem, because he is not controlling the perception he would normally control by using the protocol he has tried to initiate.

Marcel has a worse problem than John, because from his point of view, at every level (feature, syncon, or trajectory) he needs to act so that John's recognizers will produce a sufficient output. If they don't, Marcel's changes could move in any direction in the corresponding space with only a small chance of approaching a suitable trajectory for initiating the protocol John would recognize as the one Marcel wants to use, whereas John's problem is to determine only which of a sparse distribution of possibilities that belong in the situational context comes closest to matching a trajectory that he would perceive as part of a protocol initiation. Marcel has to find a trajectory in an unknown syncon space, whereas John might be able to guess what Marcel wants based on the situation.

Now consider the difference between John and Marcel when either interacts with any of the other Js. John's protocols work whenever the respondent has reference values that include controlling for John's controlled perception to have its error reduced. Collective control of John's protocol forms serves to stabilize them. Marcel's attempts at using protocols in this company do not work, but neither does collective control act on his protocol forms to correct them, since he and John do not perceive the same protocol as being attempted.

John is unlikely to reorganize just because he does not perceive what Marcel wants, except that he might possibly develop new perceptual functions that recognize consistencies in the feature patterns Marcel uses to form syncon targets. If he interacts enough with Marcel, he might even develop perceptual functions that produce output for some of Marcel's trajectories. But without being able to control any perception that uses these new perceptual functions, they are reasonably likely to be reorganized out of existence once he leaves Marcel's company. In other words, John will not have learned Marcel's language well enough to retain it for long after leaving Marcel's company, but he might have learned enough to allow him to act as an interpreter when introducing Marcel to other Js.

When Marcel leaves John, his subsequent interactions are with people who use protocols that work when they interact with John. Some of those protocols might be the ones that he worked on with John. To

Marcel, these other people have roles that we might call “being J”. “Being J” people will not have the new perceptual functions John created to perceive Marcel’s syncons and some of his trajectories. These “being J” people have not learned any of Marcel’s language, so Marcel would need to learn to perceive syncon target feature sets around the locations used by the “J” people he meets, which he might do in the same way that John learned to perceive Marcel’s.

Since Marcel is now in the company only of J people, he might even learn to emit trajectories that some J people might recognize as part of a protocol. Using them at random with various J people might result in actions that influence various of his perceptions. His situation at that point would be like Len’s when Len can produce the features but not control them individually (Figure II.12.2). His reorganization in frequent contact with J people would then lead to a condition analogous to Len’s in Figure II.12.7, in which he uses initiating and continuing protocols in ways that increasingly effectively influence the perceptions he wants to influence. At this point, Marcel’s protocol forms begin to be subject to collective control by the community of “being J” people.

In Marcel’s interactions with various members of his new community, he may have established a personal relationship with John, but the other individuals with whom he interacts are simply instances of the “being J” role. He, or rather his various protocol forms, are in the position of the Puck in our example of Stochastic Collective Control (Section 3.1.2), and the J’s are the players, together forming a Giant Virtual Controller we might call “Big J”.

Marcel’s protocol usage may eventually come to be like that of Big J, but it would never be identical. For one thing, the reorganization of his feature sets that form syncon targets would slow dramatically when his syncon targets began to fall into the range in which most J-people could identify which of their syncon trajectories he was attempting to produce. He would maintain as much of his “native accent” as would allow him to function within the collective “being J” tolerance zones of the various parameters of the protocols he learns to use.

Marcel is, of course, an illustrative example of a person joining a group of people in a particular role, such as member of a religious group, a sports club, a researcher into some arcane branch of parasitology. Although Marcel in the example became isolated from his native group, such people usually continue their membership in their original groups. A person can be a native of some town, belong to a rugby club, be a Catholic, and study parasitology, and use appropriately all the protocols that allow him to be understood in all of those roles.

Protocols that work in the boozy after-match rugby club would probably not work well in the conversations after a Catholic mass, and protocols that influence the course of parasitology research would not work with a person, even another parasitologist, while playing the role of rugby player. As most people move from one role to another many times over the course of a day, so the set of protocols they can use also changes. In this sense, most people are polyglot, even though in all of their roles they may speak the same “language” be it “English”, “Chinese”, or “Swahili”.

Marcel’s problem and its solution are not limited to synthetic quasi-humans. Watson et al. (2015) showed that a group of chimpanzees introduced into an environment that contained an existing group shifted their accent in referring to foods so as to converge with the pre-existing group, but did so only if the two groups established friendly relations.

The inverse may be true of human groups that become antagonists after contact. They may exaggerate contrastive ways of speaking to ensure their identification is with the “correct” group. The effect is much like that of the lateral inhibition induced by the HaH process, as we discuss when we treat language drift.

III.3.6 Modular networks revisited

Among the extended J clan visited by Marcel are siblings Joe and Jane. They have sibling cousins named Jill and Jack. The cousins are acquainted with each other, but have only occasional contact, such as at family reunions and a few other occasions. Over time, the protocols used by each branch of the family have drifted a little way from those used by Len and Sophie, or by Dan and his siblings, the senior Jack and Jill. Many of the protocols are the same, but there are some new ones for situations not encountered by their ancestors, and both branches of the family might perform some of the ancestral protocols a little differently.

If Joe and Jane and their close family were the only ones involved, the shifts could go in any direction without causing problems. But if the Joe and Jane branch of the family had reorganized differently from that of Jill and Jack the younger, Joe and Jane would not easily be able to use their shifted protocols with their distant cousins. Sometimes their protocols would work properly, to control the perceptions the protocol initiator tried to control, but sometimes the disturbance to the cousin's controlled perception might result in entirely unwanted control actions.

For example, Jack might not be able to use with Joe the same "What do you mean" protocol that Jill would perceive as a request to display his intent. Joe might not even perceive that Jack was uncertain about what Joe was intending to do, and even with goodwill toward Jack, Joe might then act to disturb Jack's perception in a way that created a positive feedback loop, creating a conflict that could escalate to a family quarrel and in extreme cases, estrangement.

Protocol failures imply that more reorganization would occur when cross-group interactions occurred (as suggested in Figure III.3.3). The result of this reorganization would be that the shifted pronunciation or protocol usage would become at least mutually intelligible among all four of them. In other words, either the groups would split and lose contact or their protocols for the particular contexts in which they interact would converge.

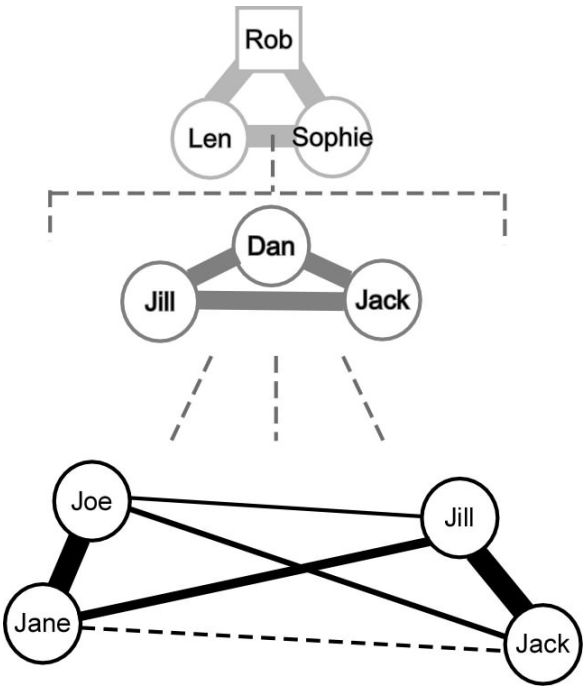


Figure III.3.3. Descendants of Sophie and Len may have different frequencies of interacting with each other. Joe interacts frequently with his sister Jane, and the younger Jill with Jack, and both pairs have reorganized to use protocols that work well within the pair. But can Jane interact effectively with distant cousin Jill? If they interact enough, Jane and Jill will reorganize so that their protocols converge, and Joe and Jack will reorganize to bring their protocol forms closer to the converged forms developed by Jill and Jane. The whole group would be likely to develop a common language with family idiosyncrasies.

If the cousins had been many generations separated, and the families had been out of contact for a long time until their recent set of encounters, their "languages" might have drifted so far apart as to be mutually unintelligible, rendering many protocols quite useless. If, however, control of their perceptions required cooperation across the divide, as suggested in Figure III.2.3, they might well reorganize to create a pidgin or even a creole, using simplified elements from each of their family languages in an amalgam that allowed them to understand what protocol each was trying to perform.

As always, however, even if the difference between the dialects of the two family branches was relatively small, the accommodations of different people's reorganization would not leave them with exact replicas of each other's shifted versions. Reorganization slows dramatically when control works well, which in this case means when the protocols are well understood. If Andy interacts more often with Ben than with Charlie, and Ben more with Charlie than with Doris, … and Xavier more with Yolanda than with Zeke, Charlie's language would be quite like Andy's, and Ewan's would be quite like Charlie's, but less like Andy's, while Greg's would be distinctly different from Andy's while being like Ewan's. It is quite probable that the drifted protocol used by Xavier, Yolanda, and Zeke would fail utterly to be understood by Andy, Ben and Charlie, though perhaps the form used by Lou, Mike, and Natalie could be understood, if with difficulty, by both[10].

Even if all of them live in the same community, they may live on opposite sides of the tracks, which affects how often different pairs of people interact. If the people who live "on the wrong side of the tracks" interact across the tracks much less often than they interact on the same side of the tracks (Figure III.3.4), the two sets of protocols are likely to diverge in three ways. Firstly, the pronunciations used on the two sides of the tracks may drift differently; secondly, the perceptions controlled by the continuers in the preferred protocols for a particular purpose may change; and thirdly, completely new protocols may be independently developed to suit different situations that might occur on the two sides of the tracks. All of these are probably at work in the splitting apart of the Korean language between North and South Korea since about 1950.

10. In natural languages, think of the relationships between French, Piedmontese, and Italian, or French, Catalan, and Spanish, the middle one in each case being both geographically and linguistically intermediate between the others.

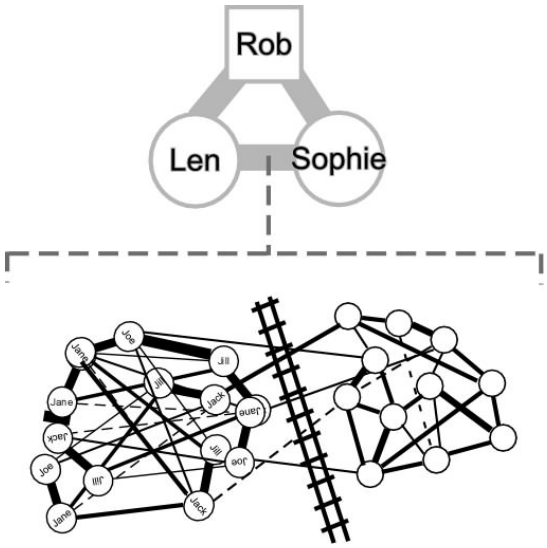


Figure III.3.4. Groups tend to cluster into subgroups that are more tightly linked within than between the subgroups. Here, two sets of Len-Sophie descendants are separated by "tracks", Each set being "on the wrong side of the tracks, as perceived by the other. There is much less interaction between pairs who are on the opposite sides of the track than between pairs on the same side. Protocol forms are likely to be consistent on each side of the track, but to be divergent in detail across the tracks.

Communication might still be possible between members of different subgroups, but not all their protocols would work properly. Some might even be misunderstood and treated as provocations ("Who ya lookin' at, man?) rather than as communications, because the initiating protocol is intended to disturb a controlled perception in the partner for which the control actions have reorganized to produce actions other than those the initiating partner expects from that protocol. Of such misunderstandings can wars be based.

III.3.7 Conflict and Crumpling

The crumpling metaphor offers another view on conflict and stiffness,. This view is based not on the efforts of two individuals or collectives to bring a common perceived variable value to different reference values, but on differences in their perceptions of their common environment, as though I say the grass is yellow and you say it is blue, while we both control for it to be green. Our reference values are the same, but the means to get there from where we are differ. I may use some kind of fertilizer that would make the grass bluer and therefore green rather than yellow, while you use some chemical that would make the grass yellower and therefore more green rather than blue. We agree on what we want, but disagree over what we have, and therefore about how we should act.

The consciously perceived environment consists of coherent groups of perceptual properties we call "objects", whether those properties are states of the physical environment we sense directly, or are properties we are told about by others. In Chapter II.6. we called objects in Perceptual Reality (PR) "facet-objects" when we were thinking about two object categories distinguished only in that they differ in the acceptable values of a perception that crosses a crumpling "crease". In this Chapter we have two control hierarchies in different individuals who disagree about which side of the same crease the analogue

value of the differentiating perception lies. The colour of the grass is just one of the many properties of the grass, but you and I largely agree on those other properties.

This is a situation we did not encounter when discussing crumpling in an individual's perceptual control hierarchy, so it is worth a few words before we move on. In Chapter II.6 we concluded that the distinguishing characteristic of facets that differ across a crease is the use of the object as an atenfel for control of at least one higher-level perception. In other words, objects in PR differ across a crease by the actions that might use them in controlling perceptions of the same environmental state, at whatever level in the hierarchy that state might be.

It doesn't matter whether the separation is within an individual, who would treat different perceived values as being of different objects with different means of control and different uses as atenfels, or between two individuals (or collective Giant Virtual Controllers), who likewise would treat their different perceptions of the same environmental state differently. The distinction between the individual and the social is that in the social case, the actions controlling the different perceptions can be performed simultaneously, which is not the case in an individual who at any one time perceives only one analogue value of the "crease-crossing" perception.

Since in the social case, even if the situation being perceived is the same for both parties, if they perceive it as belonging on different sides of a crease in an otherwise similar facet-object, they can easily be involved in a conflict that is functionally much the same as the "classic" conflict demonstrated by McClelland (1993) in which two controllers have different reference values for the same perception of the same environmental property. In both the "classic" and the "cross-crease" conflict, the parties use incompatible, perhaps directly opposed, actions to reduce the error in a perception they control.

Why might two individuals (or collectives) perceiving the same property of the environment perceive it differently, and therefore act in opposition? We saw the colour of the grass with our own eyes, but we have not seen other properties, such as the longitudinal elasticity of the average blade, or the effect of mowing to a certain depth on future growth in the weather that is forecast for the next several days. Others have told us about those functional properties, if we perceive them at all. What others tell us, such as a weather forecast or the atomic weight of some element, is in many cases not something they had perceived with their own eyes, but something they were told, read about, or constructed for themselves, as is the case for almost everything I tell you in this book. Here we enter the realm of Trust (Chapter III.6).

I have not personally observed (measured) rattling, because I have never done the appropriate measurement in the appropriate kind of experiment. Nevertheless, I trust what I read in the paper about it by Chvykov et al. (2021), partly because it appeared in a reputable journal (Science), and partly because it connects cleanly with what I already believed, not about rattling itself, but about other statistical measures, and about things like the winter-leaf effect. Neither have I ever analyzed the crease patterns of crumpled paper, but in the same way I trust the analysis of Andrejevic et al. (2021) to have been done and to have been properly described by the mathematics in their paper, which also was in a reputable journal (Nature Communications).

Having all that compatible background set of beliefs, much of which I had learned by being told by others, such as family elders and schoolteachers, I could use my own logic to make sense of what they wrote. I could then link their measurement of the uncertainty of the velocity of variation of some property to other statistics of the variables of interest such as variance of perceptual values during control.

In Chapter II.6 we identified a facet not yet creased by crumpling with a type of object separated from other kinds of object by the ranges of perceptible variable values appropriate to each type. The entire world of "objects" is defined by the structural coherence of packages of perceptible properties (Chapter 10), distinguished by particular configurations of crumpling creases.

As Andrejevic et al. told us, as part of their analysis of crumpling, two clean sheets of "paper" subject to the same crumpling forces the same number of times wind up with very different precise configurations of creases, though the overall statistics of the resulting patterns are almost identical. We will argue that conflict can arise through these differences in the details of facet-objects learned by crumpling just as easily as between differences in reference levels for the same perceptions of an environmental state.

A Giant Virtual Controller (GVC) is functionally indistinguishable from a controller whose components are functioning physical entities such as perceptual functions and comparators. We have called a GVC a collective controller, but it is still a controller of only one perception of one property of nature. Two different GVCs, like two different individuals, may have the same reference value for a perception, but different perceptual values, which could be on opposite sides of a crease.

This does not mean that each individual member of a GVC perceives the Corresponding Collective Environmental Variable (CCEV) as being on the same side of a crease as the collective does. The very concept of a Collective Controller was introduced to PCT as a consequence of Conflict between two controllers with different reference values for "the same" perception, and we recognized that exactly the same conflict between controllers that perceive different values of a perception for which they have the same reference. These different values may be on opposite sides of a crease, but that does not affect the fact that the CCEV is collectively controlled.

An individual living control system will control many perceptions, each of a different property of nature, and these perceptions are of properties of perceived objects, both tangible and abstract. Consciously, one perceives objects rather than their properties. Each perceived property is perceived as a property of some object. How can a collection of individuals also be treated as doing the same?

Start by going back to the notion that a crease in a perception separates individuals as well as the possible classes fragmented by the crease in the analogue perception trace that is part of the dual network of the crease network. For every crease there is a link in the dual (Section II.6.3), and for every such link two individuals are either on the same side of the crease or on opposite sides (ignoring crumpling bends for the moment).

Any one individual can be traced from one facet to another, through all the fragmented perceptual facets for which the individual perceives a category class. The individual may see this object as blue, that as red, both as heavy, one as irregular while the other has a regular form, one as hot, the other as cold, and so forth. The individual's different category perceptions form a complete network that can be seen as representing the individual's perceptual control hierarchy at the category interface between the analogue trunk and the digital branch.

The same is true for another individual. Let us call the two individuals Adam and Beth, as we will in Chapter III.5. where they are Ph.D. students greeting a new student we called Cal. Adam is represented by a network that connects all the categories (facet-objects or properties of objects) that accord with his current perceptions of the world. Beth is represented by another such network.

Beth may perceive categories that Adam does not, and vice-versa, so their networks almost certainly differ in some respects. When we consider the relationship between Adam and Beth as individuals, categories that they do not both have in their networks are irrelevant. Beth might control for having Adam create a category he does not perceive (Beth assuming the Role of a teacher), but only when he does perceive it (bends and then creases a category at a higher level) will it become relevant to a measure of their relationship, however that measure is defined.

To have Adam create a facet Beth wants him to create is the equivalent in the category hierarchy of creating a new perceptual function in the analogue hierarchy. In the analogue hierarchy, we tend to consider building perceptual functions from the bottom up, finding new and useful ways to combine the

functions performed by different existing White Boxes into larger White Boxes, either by incorporating the older White Boxes as wholes or by recombining their constituent functions or smaller White Boxes into a new configuration.

Using the crumpling metaphor, creasing represents the opposite process. The crumpled facet represented one function in a White Box before crumpling. That function is unchanged, but two new functions are added that have a similar configuration of input values, but are distinguished by the addition of another input parameter (which side of the crease is the analogue value of a previously uncreased perception). The result is the creation of two new functions that entail different control actions, in the form of new interior White Boxes. Crumpling builds perceptual functions top-down, in contrast to the recombination of perceptual functions normally considered in Perceptual Control Theory. The two processes work together in reorganizing the perceptual control hierarchy in both its branches.

Perceptual functions produce analogue scalar values for the properties of objects. When deciding on a category to which an object belongs, at least some of these values have ranges appropriate to one possibility and not the other. When Beth is teaching Adam to create a crease that fragments an existing category such as colour into specific colours such as red or blue, she must guide him to perceive a functional action output difference between some objects coloured red and others coloured blue.

What the action difference is does not matter. Perhaps Beth knows that Adam's wife dislikes red in the décor of a room but likes blue, but has avoided mentioning the topic to Adam. Perhaps she want to teach Adam to distinguish a British military vessel that flies a flag with a blue field from a merchant vessel whose field is red. What matters is that there are circumstances in which Adam might need to act differently for red than for blue.

This is not all, however. Adam may learn to appreciate that some things are red and others are blue, but the analogue value ranges and the crease location for each may differ sharply between them, so that they may differ sharply on whether this or that object is red or blue[11]. It might escape their notice that their boundaries differ, each thinking that they perceive the world correctly, at least in that one property of one object, but near the bend or crease, they may well perceive the analogue value identically (which neither can ever know), but be in violent opposition about the category value, the object type to which this facet belongs.

These differences must figure into measures of the difference or similarity between the personal networks through the object-facet hierarchies of two individuals. To a certain level, since they are the same species, evolution has provided them with the same set of basic perceptions — those at the base of the analogue perceptual control hierarchy. As the baby learns to control those perceptions, the environment determines which actions work to control which of these perceptions. All normal babies turn into toddlers in much the same way at much the same age, and do so in much the same sequence (Plooij, F several references).

What all normal babies do not do the same way is learn to perceive categories relevant to controlling differently in different environments, including social environments. Adam and Beth live in similar social environments, so it makes sense for Beth to try to teach Adam to crumple his perceptual environment as she does. If Adam then uses the crease patterns Beth taught him, he will communicate more easily with people whose categories are like Beth's than with those who have learned different categories. and

11. My wife and I have this problem between blue and green. There is a range of hues for which she may ask me to get "the green one", and when I come back saying I can't find a green one, she might fetch it herself and say that it was easy to see, to which I could easily respond "If you meant a blue one, why did you ask for a green one".

therefore perceive different kinds of objects in their world. Those differences must figure in the measure of differences among personal category networks.

III.3.8 Other People as Black Boxes

When we encounter a conflict based on different perceptions of the same environmental situation, we have two options (at least) to directly reduce the rattling created by the contrasting actions to control those different perceptions. One is to withdraw and in essence say "You believe what you want. I'm not going to listen to you or try to change your belief." The other option is to act so as to overwhelm the other, so that their actions can no longer disturb our perceptions.

There is, however, a more difficult and perhaps subtler approach to resolving this kind of "cross-crease" conflict, and that is to understand what the other is perceiving and wants to perceive. Those are things that nobody can perceive directly. They must be inferred. In Chapter 11 we called this kind of inference the construction in PR of a White Box that emulated the Black Box that is on this occasion some part of the other person rather than all of Real Reality. When we want to figure out what another is perceiving and wanting, we need not try to build a complete White Box model of the individual. All we need is that chunk.

Other people are always Black Boxes whose functioning we cannot observe except through their observable interactions with the outer world. If we want to understand them, we must create White Boxes that perform functionally as those Black Box other people do. Figure III.10.1 (Figure 11.2 repeated) shows the relationship between two individuals, one (who we identify as a psychological theorist, though that individual probably not self identify as such and might even be a toddler newly learning to use language).

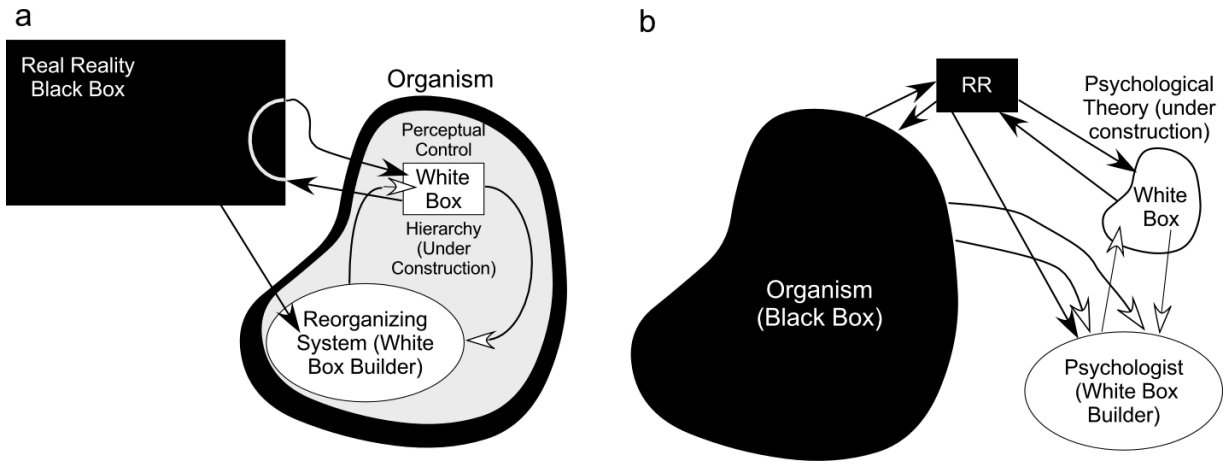


Figure III.10.1 An outline sketch of the problem facing a person we call a psychological theorist, (though that person might even be a young child), trying to understand the perceptual properties another person is controlling. (a) An organism creates by reorganization a White Box emulator of a part of Real Reality. (b) another person does the same for the Black Box object that is the first person, who is part of her own unknowable Real Reality.

The toddler might do this by analyzing the White Boxes that have been constructed by the other person to represent Real Reality (RR). To the toddler, the construction that is a White Box to the other individual is inscrutable. It is a Black Box. Neither the toddler nor someone simply trying to understand what another is perceiving and wanting will construct a general White Box of the other individual. Either

will create White Boxes of only the Boxes of the other individual that produce "interesting" actions. Those Boxes are Black to the one trying to understand, White to the individual being understood (Figure III.10.1).

Figure III.10.1 shows only the person represented in the right panel trying to understand something about the person shown in the left panel. However, at the same time, the relationship may be reversed, with the person in the left panel trying to create White Boxes to represent the person in the right panel. In both individuals, the structure of Black Boxes being emulated changes during construction, creating a feedback loop between the sets of White Boxes being created to emulate each other's (Black) White Boxes.[12]

Since each person's White Boxes for the part of Real Reality that excludes the other is not subject to this particular feedback loop, that part of RR provides a context for a development we call "mutual (mis)understanding".

A mutual understanding is not so much about the value of a single perception of a property of an object, but about the identity (set of agreed property values — perceptions) of an object. A misunderstanding can be represented by a crease that separates the same kind of object, a crumpling facet, in each individual from that perceived by the other. It is a crease in a "social facet". A mutual understanding thus represents an uncreased social facet-object shared between the two individuals. These individuals perceive the environment similarly, at least insofar as the White Boxes they have so far constructed to represent each other can determine.

But what is an object on which they both agree? Is it something in the environment for which each has constructed a similar White Box? That something on which they cannot agree, because neither can perceive the other's White Box representing that object in the environment. What each is constructing is their own White Box model of the other's White Box, which to them is Black.

Remember that a White Box is a container for one or more functions. It has input and output terminals, just like Wiener's original hypothetical Black Box. When the White Box is seen as an Object in Object-Oriented Programming (OOP), it is a "class object" of which there may be many instances. Each function performed by that Object is a perceptual function, of which there may also be many instances with different connections to its input in the form of perceptions from lower levels and output as a perception to higher levels.

We return to the feedback loop of White Box constructions between individuals (or collectives) What each is creating is a model of something that is a model of something, an abstraction of an abstraction disconnected from direct sensory evidence, since neither can know what, if any, sensory evidence the other used to construct the White (Black to them) Box they are trying to model. The end point of this feedback process, if it ends in an understanding, is an abstraction, based only on the interaction between them.

If it diverges into a misunderstanding, the model each has made of the other may or may not be correct in any or many of the properties each built of the other's White Boxes of their environments. Either way, the constructed White Boxes represent functioning abstract structures built from perceptions some controllable, some not. The two individuals probably have built into their White Boxes of each other methods of reducing or avoiding rattling each other by the direct effects or side-effects of their actions.

12. In everyday language, person A is trying to understand how person B currently understands person A. These, incidentally, are the three "nested levels of belief" about the three propositions whose answers define the current network locations of the parties engaged in a protocol.

In the misunderstanding situation, the total rattling of the organization is likely to be increased by continued interactions between the individuals. The rattling may be reduced in the individuals, and therefore over the organization as a whole, by separating the individuals that misunderstand each other's view of a situation, eliminating or severely reducing their interactions.

We see this effect in what has been called the "echo-chambers" of social media, in which individuals tend to communicate preferentially with others that share their opinions, forming collective controllers of various perceived properties of different abstract objects (Chapter 37). We will use these effects in the later Sections, but for now "we return to your regularly scheduled programming".

Part 8: Community: Truth and Trust

"What is truth" asked Pilate two thousand years ago, and we may well be tempted to ask the same question today. From a PCT viewpoint, the only guaranteed truth each of us can have is that our perceptions are what they are. But this is a rather unsatisfactory answer to the question, I think.

Perhaps we can use the theory itself to propose answers that better fit the purposes for which we want truth. One of those purposes is often to be able to use popular protocols effectively — to get along in our culture. If others with whom we interact believe certain things to be truths, we can use those beliefs in controlling our own perceptions during our interactions with them. If we also believe those same things to be truths, or act so that the others believe that we do, we will be more likely to be perceived as members of the culture than if we do not.

To be perceived as a member of the culture to which your communication partner belongs allows the other to trust that what you say is the truth. If I try to borrow money from you and promise to pay it back, you are more likely to lend it to me if you understand that I have a background like yours, whether that background be as an upstanding member of your church or as a member of the same gang of thieves. The phrase "honour among thieves" is not a self-contradiction.

This part of the book begins with a discussion of the nature of artifacts, among which we include not only tangible artifacts such as tables and chairs, but also collectively controlled variables that define the forms of language and the manners and protocols that define a "culture". We ask whether perhaps truth itself might be an artifact. We look at the development and function of social and cultural "norms" to which members of a social group would be expected to conform. Among these are that a specially shaped and patterned piece of paper money can act as an atenex for the control of many different kinds of perception that require for their control the actions of other people. Here we will encounter another kind of perceptual control motif, the "trade motif".

Many kinds of cultural norm include certain beliefs that tend to cohere together as a consistent structure that can be used in creating reference values for perceptual control. They are higher-level perceptions just like perceptions based on direct observation of the physical environment. Whether those beliefs conform to the real world is one aspect of "truth", but to what extent this matters depends largely on how the truth can be tested in actual control.

If someone tells you that the sky is green, you probably could test the truth of that statement by looking at the sky. It can be tested. But most things someone tells you are harder to test, and for those, your perception of their truth depends on your perception of the trustworthiness of the teller. If someone tells you that Morbidia is a nation that spawns terrorist cells that infiltrate your own country ready to kill at random, and that Morbidians look and act just like everyone else you will meet, how would you test that fact? Perhaps you might question its truth, but even if you do, you might be a little more fearful of your neighbours and passers-by on the street. If you trust the person who tells you, you might believe it is true, but if you previously knew geography well enough to know that there is no nation called Morbidia, you probably would not.

All of the things people tell you might possibly become part of your model of "*the way the world is*" or "*the way the world works*", even if some of them contradict others. In principle, as we discussed in Chapter 10 and Chapter 11, it is possible to discover by control tests *the way the world works*, but never the real reality *way the world is*. The whole enterprise of science is a collective attempt to determine the way the world works, though it is often cloaked in verbiage purporting to show the way the world is. Even within science, contradictions often last detected or undetected, as is currently the case between the two extremely precise predictive theories of general relativity and quantum electrodynamics, which cannot both correctly describe the same Universe.

Contradictions among the different things people tell you about either may not become apparent until both sides of the contradiction are used in controlling the same perception, in which case we can run into conflict and stiffness before one side or the other of the contradiction is eliminated. We argue that truth becomes largely an artifact that can be used as a tool by those that form it.

In Section III.7.4 we introduce "Harvey", Mr. Dowd's invisible rabbit[13], as an example of all the "convenient myths" that hold cultures together and distinguish them from other cultures. Harvey can be known only because Mr. Dowd tells you about him and what he tells Mr. Dowd. The believers in Harvey sometimes have difficulties in dealing with non-believers, which tends to make Harvey a tool for keeping the cultural group bonded together. Harvey is a "convenient myth".

13. Concept taken from the 1944 play and 1950 movie "Harvey", the latter starring James Stewart as Elwood P. Dowd.

Chapter III.4. Categories, Consciousness, Communication, Community

To this point in the book, we have followed several apparently unrelated trains of thought, some seemingly unrelated to the Powers Hierarchic Perceptual Control Theory. But unrelated they are not. They all come together in what Powers called the category level of his hierarchy and I call the Category Interface between two distinct control hierarchies (Section I.9.7), one in which all the "neural currents" take on continuously variable values, the other in which the values are separable and potentially open to labelling. In this Chapter we look a little more deeply into this "Category Interface" and find that it carries some important implications.

qIII.4.1 Re-thinking the Category Interface.

In Chapter II.10, the Category Interface is the separator between conscious thought and the non-conscious perceptual control hierarchy. Now we look a little further into it. What we call the "Category Interface" is not a separation between categories in the form of different perceptual input functions in the hierarchy and categories as objects of consciousness, but the distinction between the overlapping "soft" or "fuzzy" categories of the non-conscious perceptual control hierarchy and the "hard-bounded" or "classical-logical" categories of conscious thought.

In conscious thought, a non-flying creature with wings and feathers such as an ostrich or a penguin may sometimes not be included among "birds", depending on what characteristics of the "bird" category are required for the argument. In the non-conscious perceptual control hierarchy, they are simply categories of living things that overlap in their perceptual function inputs with a category that includes seagulls, eagles, and humming-birds. When we talked about crumpling in Chapter II.6, we considered the categories as indefinitely distinguishable, penguins being on a different side of a crumpling crease than others that belong in the larger category that might be labelled as "birds". The interface separates the continuously variable importances of the underlying properties from the crease-separated divisions of "this is NOT that".

In Chapter II.1, we introduced the concept of autocatalytic loops, but there we treated the variables as continuous. If we are dealing with atoms and molecules, we have to identify which kind — category — of atom or molecule each reactor and catalyst is. A chlorine atom will not react equally readily with an oxygen atom and with a gold atom. The pairwise reactivity may have a magnitude that an be measured on a continuous scale, but the "goldness" of an atom cannot. An atom either is or is not an atom of gold, whether it is labelled or not. What IS continuously variable, or sufficiently fine-grained to be treated as continuous, is the concentration of chlorine atoms, oxygen atoms, or gold atoms in the substrate "soup". The concentration affects the likelihood that an atom of one kind will actually meet an atom of a particular other kind and react with it.

When we want to talk about anything, as T.S. Eliot wrote (Section 2.6) "*I gotta use words when I talk to you.*" One word is not the same as another word, though the pronunciations may shade into each other, and in actual speech they might be confusable out of context. What a word labels is a category, whether that category be an object, a relationship, an action, a modulation such as an adjective or an adverb (categories all), none of which is a value of a perception that is intermediate between any of the others.

Categories have categorical relationships, as words have relationships that as groups we call syntax and semantics. Although I must words to describe a relationship, the relationship is not created by the words. As Korzybski (1933) said, "The map is not the territory", and neither is the verbal explanation the

thing explained. When we consciously imagine some thing, relationship, situation, or theorem, we image relationships among categories, not values. Even when our imagination does involve some continuously variable value, it is ordinarily in the form of “big enough”, “less than”, or “between”, each of which defines a category.

So far in the book, we have come at categories in different ways, one of which is the crumpling metaphor that we explored in Chapters II.6 and II.7. The crumpling metaphor allows us to link entire objects, which are what we consciously perceive, with the properties that we control in the main perceptual control hierarchy. The categorical facets produced by crumpling are facets of objects, and when we act, we interact with objects (concrete or abstract collections of properties) in order to manipulate the property we are perceiving and controlling.

When one interacts with an object in order to control one perception, other properties of the object are likely to be disturbed as side-effects of the control action. For example, as we described in Section I.5.4 we pointed out that you can’t move one leg of a chair without moving other parts of the chair as well. These “intra-object” side effects are inevitable for a solid object such as a wooden chair. But even (or especially) in a tensegrity object, the effects of changing one property are distributed throughout the object.

The distribution of side-effects within an object leads us to contemplate the nature of an object and its environment. Here we are talking about the distribution of rattling effects, since the side-effects of disturbing a controlled property of an object create inherently unexpected (i.e. internally unpredicted) disturbance to the values of other properties of the object (as well as properties of other objects, which we have hitherto been discussing. This is as true of an abstract object as of a concrete one, but in either case, the rattling (uncertainty of the rate of change of the variable being measured) effect on the different affected properties of a single object is far from independent.

These considerations are within the “one-dimensional controlled perception” frame, but in consciousness we perceive objects, including their properties on some occasions, independent of their properties on other occasions. In consciousness, property ranges become categories, not values on a continuum, though those values can be consciously perceived in the case of an instance of the catagory. When talking to someone else, an instance of the category “chair” might be “the soft red chair”, “soft” and “red” both labelling sub-categories of “chair”, and identifying an instance of “chair” as an entire object that has many controllable properties, such as its location, ownership, or who is sitting in it at the moment.

III.4.1 Consciously Perceived Objects as Hypernodes

There have been many speculative suggestions over the centuries about what consciousness is, and some about how it comes to be. PCT may be able to make a small contribution to this parade of speculation.

We start by observing that we consciously perceive the world as being full of objects in a contextual field, whereas we control not the objects as wholes but only the values of their properties such as location, hardness, colour, configuration, and so forth. By that observation we have made a clear distinction between conscious perception and the perceptions being controlled within the non-conscious perceptual control hierarchy. Objects cannot exist as perceptions within the non-conscious hierarchy because they cannot be described by a single number that represents their current magnitude or value.

Earlier we identified Wiener's "White Boxes" and "Black Boxes" with Objects as the word is used in Object-Oriented-Programming (OOP). An OOP Object has a wholly opaque skin around an internal structure that is accessible through the relationships among variations of its inputs and variations of its outputs. A programmer given the input-output specification for an OOP Object is free to use any programming technique whatever to fulfil those specifications. To the programmer, the box is White, to anyone else, it is Black.

The programmer of an OOP Object might well use OOP technology in the programming, building the specified Object out of smaller Objects. We will argue that what we perceive as objects with their own properties are functionally precisely the same as OOP objects, to the degree that we will sometimes treat them and Black Boxes as though they were all one and the same. Wiener's White Boxes are created not according to specifications handed to a programmer, but so that they mimic any relations between the Black Box input and output terminals that have been detected by observing how the Black Box behaves when provided with test inputs (often random noise).

Since the Object, either phenomenal, Black Box or OOP, is exactly as inscrutable (and "scrutable") as its equivalent in real reality (RR), the same analytic technique can in principle be applied to it as was used to describe RR in terms of functionally interconnected White Boxes. Regardless of the actual interior structure of the inscrutable Object, its functionality can be emulated by a suitable interconnected set of smaller Objects. White Boxes may be built from sets of smaller White Boxes. Perfect emulation is all we can hope for when we have only the input and output signals to work with, and a sufficient deeply nested internal collection of White Boxes within White Boxes (perceptual Objects that are components of other perceptual Objects such as chair legs as components of chairs) can behave arbitrarily close to perfect emulation.

When we are talking about perceptual objects, we are talking about consciously perceived entities that seem to have perceptible properties, many of which have controllable values. Given inputs from somewhere, these properties imply processes that produce perceptions as outputs. These processes necessarily are perceptual functions. Perceptual functions take as inputs sensory data, lower-level perceptions that are the outputs of perceptual functions, or perceptions derived from memory or from the imagination. Any perceived Object has many properties, all of which imply the existence of a perceptual function, so a perceived Object can be seen as a collection of perceptual functions, exactly as shown when discussing the construction of hypernodes. A perceived Object, then, is a hypernode in the perceptual control hierarchy, and the successive levels of hypernode construction correspond to the levels in the perceptual control hierarchy.

No matter whether we are talking about an Object that we perceive, such as a house, a car, or an abstract object such as a social club, an Object that a programmer uses in Object-Oriented Programming, or a Wiener-type Black (or white) box, the same considerations apply: These relationships among the

smaller internal Objects are the functional properties of an Object, and there may be many in a high-level Object, all of which involve lower-level Objects for their implementation. None of these need their implementations to be described — they are just objects with certain functional properties. If they are perceived objects, they are necessarily atenexes, potentially useful in the control of some perception under some conditions.

The values of the signals at the input and output terminals of an Object at any moment are property values, which in slightly more mathematical language are the arguments to the internal functions of an Object and the results of applying the functions to those argument values. The functions embodied in the properties of the Object are entirely cognate with perceptual functions in the perceptual control hierarchy, with input and output signal values corresponding to perceptual values from lower levels and output to higher levels of the hierarchy. The interior Objects are thus cognate with lower level perceptual functions that provide inputs to the perceptual functions realized by the containing Object. Figure II.1.13 is the network of Figure II.1.11 drawn with a different layout to suggest perceptual levels.

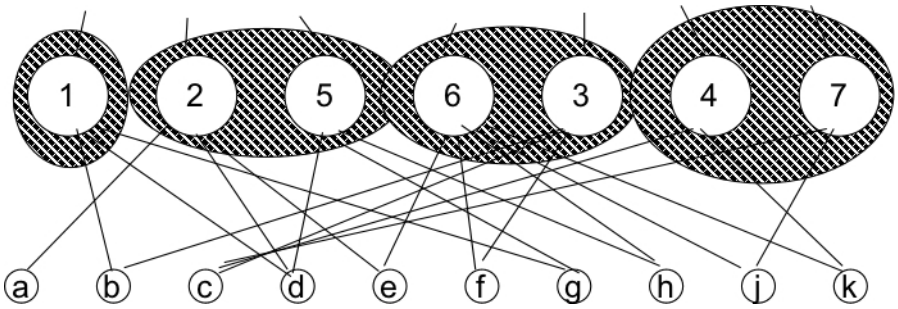


Figure II.1.13 The hypernode structure of Figure II.1.11 shown as a pair of perceptual levels. Node with numbers represent perceptual functions at level N, those with letters perceptual functions at level N-1.

As we have been pointing out, an Object as such has no cognate in the control hierarchy, and it must be analogous to a conceptual "membrane" that encloses a whole collection of perceptual functions at a given hierarchic level that tend to co-occur in our interactions with Real Reality. Pairwise, these co-occurring perceptual functions may and probably do share several inputs from lower level perceptual signals.

The hypernode structure can be taken to any desired level by selecting an appropriate criterion level of similarity among connection patterns. In selecting this first level structure using Table 13.2, we chose a criterion dissimilarity level of 3 and below. This produced four separate hypernodes, each of which might represent a perceptual "thing" in Perceptual Reality. In Figure II.1.11 and Figure II.1.12, the nine lettered "lower-level" nodes could each represent a hypernode containing several perceptual functions, the properties of the "thing" they represent. For real life examples, a girder is a thing that is composed of beams and struts, and a book is a thing composed of pages and cover material.

Beams, struts, pages, and covers are used in things other than girders and books, but even in one girder or one book there are several instances of each. In the OOP programming language, the hypernodes are Object Classes, while each strut or page is an Instance of its class. An instance actually performs the functions defined by its class description, each instance acting on its own input and parameter values.

The Object that we perceive as a unitary "thing" in our environment is not a perception we control. We control perceptions of it properties, but not the entire object. In the language of Object Oriented Programming, a thing we consciously perceive is an Instance of a Class, of which there may be many Instances. The Instances all have the structure described by the Class, but are individual entities, like the

set of chairs arranged around a dining table. As with a programming Object, each chair may share all of the properties of the class, but also may override them. For example, the "bird" class has the property of wings that enable the bird to fly, but several subclasses such as penguins or ostriches do not, and a particular instance of a bird belonging to a "flying" subclass also my override that property if it has a broken wing.

When we recognize perceived objects as Instance of Object Classes it is possible to see how the perceptual system can allow our perceptual environment to include many pages in a single book, or many books on a library shelf. The instances are consciously perceived objects, not controllable perceptions. But any higher level Object may have a property "number of instances of Class X", as in "The book has 223 pages". That property has a value that is is a perception, usually a controllable one, but what is controlled is never the Object itself.

The preceding discussion suggests that every Object in the Perceived Reality environment is actually an atenex. Each Object corresponds to a hypernode of perceptual functions, and each perceptual function produces a perception ready to be controlled. The Object we perceive then contains the means to control the matching perception in the hypernode in the control hierarchy. In Section 11.1 we discussed the "Mirror World" that our perceptual functions create in Perceived Reality. Here we have another manifestation of that mirroring, that an Object is very likely to be an atenex that offers a range of possibilities for controlling a variety of quite different kinds of perception.

III.4.3 PCT and the "Free Energy Principle"

In the Book's Overview (Section 1.6) we claimed that PCT encompassed Predictive Coding, known as the Free Energy Principle (e.g. Friston, 2010 for a review paper). Let us examine how this is only partially true, and how the two approaches differ in a way that allows them to act symbiotically. But first, we must clarify a possible misunderstanding of "Free Energy", which actually has nothing at all to do with energy in the physical sense of force applied over a distance. As Friston uses the term, "Energy" in "Free Energy" is a purely information-theoretic term equivalent to "Mutual Uncertainty" (Section I.10.2).

With that understanding, the uncertainty relation between Friston's "Prediction" and "Result" is the same as the relation between the "Reference" and "Perception" (or CEV) of a control loop. Friston's "Result" is in fact a perception of the state of an instance in Perceptual Reality. What differs is that Predictive Coding computes in consciousness what effects on the perception different manipulations of the current environment will have, and tries to compute a way of bringing the perception of a specific instance of some category to where it "should" be. The prediction of the effects of a chosen procedure might turn out to be accurate, but unless the state change of the instance is helpful to the individual, to make the change is not very useful.

Friston's approach may well be appropriate for conscious control, which we will assert to be just what it is. Where PCT and the Free Energy Principle become easy to distinguish is not in the Free Energy Principle or Predictive Coding, but in Friston's computational use of output control, anathema to PCT. Perhaps paradoxically, it is precisely this critical difference that allows the two contrasting approaches to support one another.

We have spent many chapters describing Powers's Hierarchic Perceptual Control Theory, so if we are to hybridize it with Friston's Predictive Coding model as we did with Narrative in Chapter II.10, we should let Friston speak for himself to describe it. In the first page of his 2010 review paper, Friston says (his references have been omitted, and my comments based on PCT inserted):

Motivation: resisting a tendency to disorder*. The defining characteristic of biological systems is that they maintain their states and form in the face of a constantly changing environment.* [PCT: agree] *From the point of view of the brain, the environment includes both the external and the internal milieu.* [PCT: For this to make any sense, "the external milieu" must mean "outside the brain". I find this difficult to interpret, since it implies that the brain's view "internal view" includes itself, which is impossible.]. *This maintenance of order is seen at many levels and distinguishes biological from other self-organizing systems; indeed, the physiology of biological systems can be reduced almost entirely to their homeostasis.* [PCT: agree, with the recognition that control loops are themselves a minimal form of homeostatic loop, and that some physiological homeostatic loops incorporate parts of perceptual control loops (Section II.8.2).] *More precisely, the repertoire of physiological and sensory states in which an organism can be is limited, and these states define the organism's phenotype.* [PCT: if this simply means that surviving means that there are limits on the values of some variables, then PCT would agree, but I would call it a tautology rather than a condition from which the next sentence follows. Friston's use of "repertoire" implies discrete rather than continuous variation, or category perception.] *Mathematically, this means that the probability of these (interoceptive and exteroceptive) sensory states must have low entropy; in other words, there is a high probability that a system will be in any of a small number of states, and a low probability that it will be in the remaining states.* [PCT: The fact that Friston talks about " small number of states" reinforces that his states are discrete, having category identities rather than continuous values.] *Entropy is also the average self information or 'surprise' (more formally, it is the negative log-probability of an outcome).* [PCT: Entropy has nothing to do with an outcome. It is a property of any ensemble. However, it is correct to say that the less probable is the result within the ensemble of possible results of an observation before the observation, the more information it provides] *Here, 'a fish out of water' would be in a surprising state (both emotionally and mathematically). A fish that frequently forsook water would have high entropy* [PCT: presumably our first land-living ancestors and present-day lungfish were not in fact living, if Friston is to be believed in claiming that living things are of low entropy]. *Note that both surprise and entropy depend on the agent: what is surprising for one agent (for example, being out of water) may not be surprising for another* [PCT: "for one agent", this is true, but also for that agent in a one situation but not in another. For example, to meet your next-door neighbour on the street near your house is not surprising, but to meet him as the first person you talk to on your first visit to a new country after having not seen or heard from him for several years would be surprising[14]]. *Biological agents must therefore minimize the long-term*

14. This actually did happen to me in 1949. The first American I spoke to on arriving in New York by ship was the elevator-attendant in our hotel, who turned out to have been billeted as a US Marine in the house next to ours in England in 1943-44.

average of surprise to ensure that their sensory entropy remains low [PCT: it's not their sensory entropy as such, but the mutual uncertainty between their reference values and their perceptual values. However, Friston's wording perhaps make more sense in the context of rattling (Chapter II.5), since high but localized surprise implies high rattling, and that tends to lead to restructuring of organizations, including reorganization of the perceptual control hierarchy in an individual living control system.]. *In other words, biological systems somehow manage to violate the fluctuation theorem, which generalizes the second law of thermodynamics* [PCT: somewhat agree. That is the point of all life, and it is what perceptual control does. It's no mystery, however, as is implied by Friston's "somehow", since almost three-quarters of a century ago Prigogine identified how the apparent violation of the Second Law of Thermodynamics, which applies only to isolated systems, is a result of self-organization in a non-equilibrium energy flow (Prigogine, 1947). Life just happens to be an important example of the effect in practice.]

Considered from a PCT viewpoint, in the first section of "Box 1" of his Review article Friston describes a necessary consequence of controlling perception, while in the "Optimizing" sections he describes the results of reorganization built upon the results of evolution. Here is a rough translation using some of the language of PCT instead of the mathematical language used by Friston.

Part a of the figure [not included here] *shows the functional relationships among the quantities in a control loop. These include the internal time-varying perceptual values and reference values μ(t) and quantities representing the interface with the environment, sensory inputs and action outputs. The environment is described by equations that specify the effects of the output on its (hidden) complex variables. The complex variables are influenced also by randomly varying disturbances whose variations are represented by a variable θ. The values of these complex environmental variables are represented with precision γ in the perceptual states. Free energy is a function of sensory input and a probabilistic representation in the perceptions μ of the actual states of the hidden environmental variables (the CEVs).*

The free energy depends on two probability densities[15]*, the probabilistic relationship between the CEVs and their corresponding perceptual values and the probabilistic relation between the effects of disturbances and outputs on the CEVs. This latter is produced by a model in the brain, given the variation parameter θ. Part b of the figure provides provides alternative* ***expressions for the free energy to show what its minimization entails: action can reduce free energy only by increasing accuracy*** [MMT Note: Emphasis mine. In PCT-speak action can reduce the total error only by making the match between perception and reference more accurate — a tautology in PCT, but also a translation of what Friston says]. *Conversely, improving the perceptual representation of the real world and the internal model of the effects*

15. Note that in this formulation "Free Energy" is a dimensionless probability measure akin to covariance, not a kind of physical energy measured in joules. It is the Mutual Uncertainty between the reference and the perception or CEV in a perceptual control loop and between the prediction and the variable to be acted on to produce the desired perceptual effect in Friston's model.

of action on the environment improves the ability to avoid large effects of disturbance on error values.

To this point, what Friston says can be put more simply in PCT, more simply in PCT because Friston follows the "control of output" class of theories, and relies on explicit and computationally expensive modelling to decide what to do in order to have some specified effect on the perception. No such modelling is required in PCT for perceptions whose control has already been reorganized into the non-conscious perceptual control hierarchy, beyond ensuring that at each level of the hierarchy the direction of action keeps the loop gain negative. Having said that, Friston does not specify here any form of brain model. We will, following Seth and Friston (2016).

The Powers perceptual control hierarchy is just such a model, and reorganization that improves the precision and speed of control (precision minimizing free energy) will tend toward the effects Friston supposes to be computational targets, provided that the perception in question has been incorporated into the perceptual control hierarchy by reorganization. If it hasn't, then this "Predictive Coding" computation of outputs for control is a slow but viable alternative, and a complement to PCT.

The reorganizing process that generates and refines perceptual functions and the parameter values of the inter-level connections (founded on similar effects built-in by evolution) does minimize free energy (and rattling). For PCT, the results of this evolution–reorganization is what Friston describes in his following paragraphs (here in a PCT-translation). We discussed some of this in the introductory Section 2.1 in Volume 1.

Optimizing the sufficient statistics (representations)

Reorganization (and evolution) tend to make our perceptions correspond ever better to what exists in real reality [Note: we discuss the PCT reason for this in Chapter 11 and Chapter II.4]. *The free energy can be expressed as a composite between error variations and the mutual uncertainties between the perceptual functions and the forms of real reality variables that are approximated by the CEV. This means that the agent trends in Bayes-optimal fashion* [Note: this means informationally the best possible. The language also implies co-variance among the values of the properties perceived, which are vectors, not the individual property values PCT control loops perceive.] *toward representing real reality in its perceptions, while the error is minimized through action feedback to the perceptual value.*

Optimizing action

Acting on the environment by minimizing free energy requires that the action affects more strongly those perceptions that show most error [Note: Friston's variables are vectors, not scalar variables. Here he seems to be saying two things at once, that greater error leads to more output and that those perceptions exhibiting greater error are given priority in an undefined sense]. *This can be seen by considering both the accuracy and level in the hierarchy of the perceptual variables. Crucially, action can affect only accuracy. This means that the brain will reconfigure its perceptual apparatus to create complex perceptions that best correspond to the complexities of the hidden variables of real reality — in other words, to minimize control error overall.*

There is little here with which PCT would differ in principle, though PCT variables are the scalar components of Friston's perceptual vectors. The ordering of primacy between free energy and control accuracy might at first seem a difference, but to assert such a difference requires ignoring that "Free Energy" is another way of saying "Mutual Uncertainty". Minimizing free energy requires control, and control happens to minimize free energy. PCT derives the need for good control from the requirement of organisms to live in a disturbing world; the free-energy principle derives it from the tendency of entropy to increase in closed systems, within which the control system and all sources of potential disturbances are included. The result is the same, whichever the conceptual source.

The most important difference, I think is that PCT necessarily embodies the free energy principle, whereas Friston uses that principle in a way that leads to an emphasis on prediction that some defined form of output should produce certain effects on perceptual values and causes "surprise" when it doesn't. In that form, Friston appears to be arguing for control of output, which directly contrasts with the basic premise of PCT, that input is controlled, not output. When reorganization has not yet provided a method of controlling some perception, however, computed command, if not control, of at least one level of output is the only way to control the perception effectively.

Whether this is a critical issue, as Powers has asserted, depends very much on whether the speed of computing the proper vector of outputs and values is fast enough to deal with the speed and magnitude of disturbance variation at that perceptual level. One would not expect to have to compute how to move one's limbs when returning a tennis serve, but if you are a merely competent amateur, you might need to compute where to move in order to return your opponent's next return of the shot you are in the process of making. A high-level professional includes these counter-counter-moves in the fast reorganized hierarchy, having studied the tactics of many potential opponents, especially including the one faced today.

As has been said of highly skilled ice-hockey players, they do not go where the puck is going, but where it will be going. For any but the most consummate professionals. that is a computational problem with inputs from observing the current movements of the opposing players as well as your team-mates. In sports such as tennis, hockey, soccer and the like, whatever your skill level, getting where you have computed where to go is a perceptual control action performed by the reorganized Perceptual Control hierarchy, fast.

The Friston free-energy approach seems to describe conscious control in much the same way as does PCT. Conscious control is of perceptions whose perceptual functions may not exist in the hierarchy so far reorganized, using actions that must be thought out, using components that already have been reorganized into the hierarchy. Conscious control implies solving a puzzle, and that is just what the Predictive Coding control approach does.

That "thinking out" of possible ways to control perceptions can be a step toward reorganization, if similar circumstances recur. The second time around, rather than going through the whole long examination of possible ways to achieve perceptual control, we can consciously say to ourselves "Last time we saw this, we fond that XYZ did the job, so let's try XYZ again." And one or more of X, Y, and Z, might already be found in the reorganized non-conscious hierarchy.

Whether they are or not, the recurrence of the pattern implies the Hebbian strengthening of the synapses used, and the anti-Hebbian weakening of synapses that might have been used but were timed ineffectively for the purpose (Section 9.5). Wrong moves, not favoured by the success of the computed X, Y, and Z moves, would be laterally inhibited by selection of the correct moves. In effect, the recurrence augments inhibition of contemplated move Q, perhaps consciously deciding "Don't do Q. It didn't work the last time."

Most of the computation required by the free energy principle has already been done and incorporated in at least the lower levels of the Powers perceptual control hierarchy, leaving only the unfamiliar, higher-level, part for on-line computation to determine reference values for actions that would be computationally predicted to reduce error in this not-yet-reorganized elementary control unit. If those actions do not reduce the error, their failure is quite legitimately call "surprise". If they do, and a similar situation recurs, there is less computation to do — or to put it another way, the same synapses will be used and thus strengthened, or again not used and thus weakened — each time it happens. A new Elementary Control unit is being created and merged into the hierarchy.

Friston's approach to control provides a parallel path that works where reorganization has not yet produced the means to control this particular complex (high hierarchical level) perception. It implies that Predictive Control is analogous to, or perhaps is an example of, Kahneman's "Slow thinking" problem-solving while control by way of the reorganized perceptual control hierarchy is his complementary "Fast thinking" (Kahneman, 2011).

In the language of The Bilateral Cooperative (BLC) Model of Reading (Taylor and Taylor, 1983), the reorganized hierarchy and the Predictive Coding hierarchy of Seth and Friston (2016) are connected into two "Tracks", the former controlling perceptions built by fast interpretation of "what could be" and "what to do about it", informing and being checked by slow analysis by the latter of "what it could not be" and and "what not to do about it". The two would be interlaced at every level in support of each other. Interestingly, the very successful "AlphaFold2" code for computing protein folding — a very difficult problem — apparently uses a very similar strategy, combining an approximate method that uses prior experience with a parallel precise track built by analyzing a pairwise amino-acid distance matrix (Miller, 2021).

The same structure of parallel slow precise analytic and fast approximate tracks seems well suited to the interactions between conscious and non-conscious control. The slow track would be conscious "Predictive Coding" control, whereas the fast track is the reorganized Perceptual Control hierarchy, which may do its job non-consciously, or in marginal or full (attentive) consciousness, using already reorganized methods to control perceptions created by already constructed perceptual functions. The slow Predictive Coding process may be used to control what the fast Powers hierarchy as yet cannot, as well as to validate the perceptions and/or the already performed actions of the fast non-conscious perceptual control hierarchy (Figure q21.1).

Figure to be drawn
Figure q21.1 Two interacting levels of conscious and non-conscious parallel control methods, the left being the conscious predictive coding (Seth and Friston,2016) track or hierarchy, the right being the non-conscious (Powers) PCT perceptual control hierarchy.

The main point of Figure q21.1 is that the conscious hierarchy can receive input both from its expectations (the expected results if prediction is correct) and from the perceptual functions of the Powers hierarchy, while contributing reference values to both its own lower-level predictions and the corresponding Powers reference values.

The speeds of these two "tracks" are very different, and the faster is in each case likely initially to dominate the slower. But at the same time, the slower predictive control track is more precise, and is liable to alter the balance between the belief levels in the neural bundles (Figure 7.3) representing different possible perceptions. In the two-track BLC model of reading, which is about perception, not control, the slower track can inhibit possibilities "proposed" by the faster (perceptual hierarchy) track

with some assurance of what cannot be correct, but can only enhance the perception of what might be correct on the basis of the available perceived evidence, not guarantee its correctness.

At first sight, it appears as though the two tracks should frequently be in conflict, since they must use the same limited set of muscles in order to produce their influences on the outer environment. They can share the data from sensors, which might result in the conscious track producing possible perceptions that are not (yet) reorganized into a form of a non-conscious perceptual function.

There is an obvious way that the conscious control track could avoid output conflict with the reorganized hierarchy, and that is for it to use the lowest level output coordinations that were reorganized into the PCT hierarchy in very early infancy. These ways of moving muscles together usefully do not need to be re-thought every time a person wants to drink from a glass sitting on a table. All that the conscious track needs to do then is influence the appropriate reference values for atenfel control loops already built into the animal's hierarchy for just that purpose.

The totally conscious Predictive Coding track and the non-conscious reorganized perceptual control hierarchy differ in an important respect that we have not previously mentioned. At each level, the Predictive Coding track is likely to deal with a vector of perceptions rather than a single perception of a single property of a single object. This vector provides a context for any single controlled property, as does a facet-object produced by crumpling. Predictive Coding deals with objects (or Objects or White Boxes) rather than with just their internal functions — their properties.

The higher the perceptual level, the wider the context, in both the conscious and the non-conscious control track. But the context in the conscious Predictive Coding track consists of objects rather than properties. Because the track controls a vector of outputs from each stage to the next lower and simpler stage, its predictions are of a corresponding vector of things done by the objects in the vector loop. Whether those predictions correspond to anything wanted by the organism is unclear, but somewhere the prediction must correspond to a reference value for an object that can serve a purpose because it has a desired property, a value of a category, such as sharpness, which might be sharp enough to cut paper easily, and too non-sharp (blunt) to cut a child's skin. That is a property of a "scissors" object that could be predicted to allow a child safely to cut paper shapes, whereas a sharper or blunter object would not.

The scissors object is in a wider context, that might include, for example, a kindergarten school and other children of a similar age, a teacher, a room with windows, and so forth. The scissors would be of no use in fulfilling a prediction of the child cutting paper shapes if the teacher had provided no paper or had told the children to lie down and take a nap. The context, therefore, is an important aspect of control, at least conscious control, whether using the Predictive Control track or the reorganized hierarchy at lower levels.

***III.4.4 Being "Better" or "Worse": Self Image Categories

In Section IV.5.2 we will meet a teacher in rural Middle America who, at the request of her class, divided the students into two groups whose only distinguishing characteristic was eye colour, and told the class that one group was "better" than the other. The individual students of the "better" group began to treat individual students of the "worse" group as little more than slaves, even if to that point they had been best friends, while members of the "worse" group acted submissively, accepting the "slave" treatment as if it was their natural lot. The teacher's idea was to allow the children to feel for themselves for one day how black people in the USA might feel all the time.

Many social species collect into groups that we call “packs”, such as wolves or marmots — or humans, though humans have other words to describe their social groupings. Packs often, and perhaps in most species, have an alpha male and an alpha female to whom the other pack members show deference. Humans are no different. Families have a father and mother, or equivalent, though in a single-parent family one or other may be missing, and in such cases the eldest child of the appropriate sex will take the alpha role.

The alpha of either sex is perceived as “better” by the rest of the pack or family, who usually do not challenge the “betterness” of the alpha, and submit to the alpha, even though they may individually be more capable of controlling a wider variety of perceptions, which should give them more “worth”. One of my professors in graduate school told us of a Chicago gang study from the 1930s[16]. In that study one of the group was a very good ten-pin bowler, except when the gang leader (the “alpha”) was present, when his scores were about the average for members of the gang. Although I am not aware of other, more recent, studies that illustrate this phenomenon in humans, it seems entirely plausible from casual observation and from sayings such as “He is getting too big for his boots” and “uppity blacks”, or admonitions such as “know your place”.

The history of women's’ suffrage, at least in North Atlantic nations, provides an instructive example.

***III.4.5 Formal and Informal Education

Several criteria distinguish formal from informal education. For example, formal education occurs in a collectively controlled institution called a “school” and the material is “taught” to the students rather than being “learned” by the students through their interactions with their environments. Indeed, one casual distinction between them may be the existence of a collectively controlled curriculum for formal education, compared with the random effects of the child learning how to control perceptions they want to control at need.

We use the word “students” to indicate a formal submissive status, in a perceptual environment in which both the student and the teacher perceive the teacher to be “better” than the student. In an actual classroom, the formal submissive status implied by the student Role may not be accepted by an individual student who is in the long process of reorganizing his or her relationship organization with others, both those engaged in the same process or the adults who are presumed to know more — until the student interacts with an adult who has learned different things than the student has learned, whether those thing are in an academic syllabus or are what is sometimes called “street smarts”, ways to survive “on the street” as opposed to surviving in the familiar home (if the student has one).

Street smarts are informal learning, developing the perceptual control hierarchy, both consciously and non-consciously (Section II.10.7). Students may need to develop street smarts that they will not learn at home because the kinds of perceptions they experience at home do not include many situations they will encounter in more public surroundings. Street smarts learning is of the same kind as younger children learn in play, both “rough and tumble” (nowadays being discouraged in most school environments). Rough and tumble play does several things both for the individual’s internal processes in reorganizing the perceptual control hierarchy for physical skills and rapid control switching, and in reorganizing those perceptions that involve perceptions of the behaviours of other children.

16. I have not been able to identify this study in scholar.google.com.

Rough and tumble play is not all beneficial. Some children learn that others are more skilled than they are, and may tend to learn to be submissive and accept a "wolf pack" kind of ranked "better-worse" system in which the "better" can make demands on the "worse"[17].

**III.4.6 Sleep and Reorganization

All sufficiently complex motile living things sleep, even fruit flies (French et al. 2021). Cats sleep a lot, as any cat-owner may testify. Birds and many marine species stay active while sleeping with half their brain at a time (e.g. Mukhametov, 1984; Rattenborg, Amlaner, & Lima, 2000). Human infants sleep much of the time, or so the parents hope, and sleep less as they age, at least beyond the teenage years (Figure q21.2[18]). Sleep obviously is very important, at least to living things as complex as a fruit fly, but there is no consensus as to why. I suggest that the two tracks of perceptual control proposed in the last Section — the rapid reorganized Powers hierarchy, and the slow, thoughtful, and imaginative Predictive Coding track — may provide a more than plausible reason.

Andrejevic et al. (2021) found that the total crease length — the energy expended in making the creases — in a crumpled sheet was approximately a logarithmic function of the number of creasing cycles performed. The US National Sleep Foundation has offered on their Web site a set of "boxes" defined by ranges of age and ranges of normal sleep recommendations. Figure q21.2 plots opposite corners of these "boxes", the longest sleep with the youngest age and the opposite corner, the shortest sleep recommendation and the oldest age that define the box. The ages are plotted on a logarithmic scale, from 0.1 yr (as a proxy for zero) to 100 yr, fitted by eye with a straight line of slope approximately -2.7.

17. A personal anecdote. At one time I attended a small private school where I stayed all week, going home at weekends. I was bullied by a small group of older students, and I asked them why they were doing this. The answer was that it was a tradition handed down through the years, so that it was almost their duty, and when I reached their age, I too would bully the younger students. I determined then and there that I would not follow the tradition, and I didn't.

18. From Table 2 in https://www.sleephealthjournal.org/article/S2352-7218(15)00015-7/fulltext#secst0040 Retrieved 2021.11.12

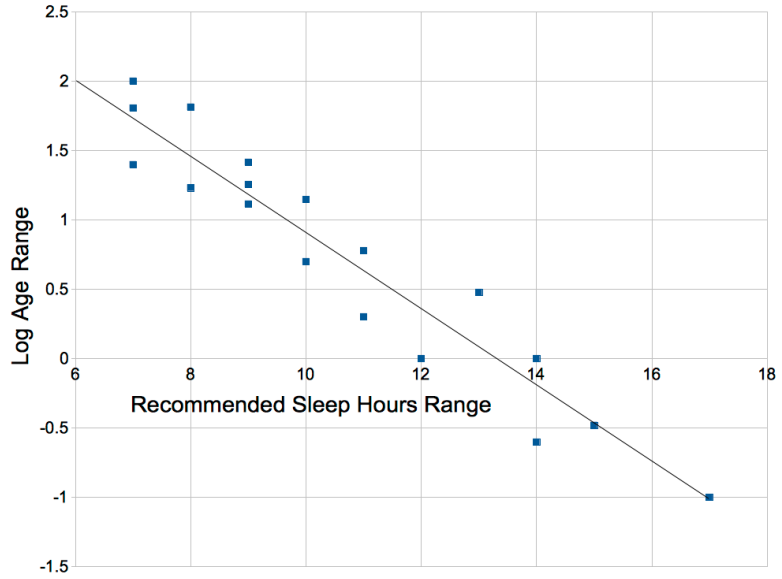


Figure q21.2 Our recommended daily hours of sleep decreases logarithmically as we age. The points are from the ranges of sleep recommended by the US National Sleep Foundation, one point from the youngest age and the longest sleep, another from the oldest and shortest sleep recommended for an age range. The line, with slope approximately -2.27 hours per decade age, was added by eye. (Graph by the author from publicly available data)

When we are asleep, we are not conscious of what is happening outside our bodies, though some sensory events may wake us up or influence the content of our dreams. The events that may wake us are outside the normal range of sensation, such as loud noises or bright flashes of light, as well as perhaps familiar perceptions that have been incorporated in the non-conscious reorganized hierarchy as creating error in a controlled perception and therefore action, such as the cry of a baby or the mention of one's name. The non-conscious workings of the brain are capable of activating its conscious processes.

Not all controlled activity during sleep is necessarily conscious. Sleep-walking apparently is not, although the sleep-walker is capable of safely negotiating a route without running into a wall or falling off a stair. What then constitutes an activity that demonstrates to an outside observer that someone or some other living being is conscious? It must be the performance of some act that controls a perception that cannot have been reorganized into the non-conscious hierarchy, given the lived experience of that living control system. It is the solving of a puzzle, or resolution of a problem, using observable action.

At this point we must ask whether we are conscious when dreaming, because dreaming occurs without observable action that relates to the content of the dream. The dream may have coherent activity, it may have content relating to the external environment, such as if one were to dream of a snowstorm or ice-skating when one is cold, or as Kekulé claimed to have dreamed of a snake eating its own tail and finding therein the clue to the carbon ring structure of benzene[19], but one thing the dream does not normally do is to coincide with related muscular activity, though a sleep-walker might later claim to have been controlling some perception(s) in the dream by actions that were used in the dream.

19. Kekulé apparently offered variant forms of this event at different times in his life <https://en.wikipedia.org/wiki/August_Kekul%C3%A9#Kekul%C3%A9's_dream>.

Apart from occasions of or akin to sleep-walking, dream perceptions and activities occur entirely in imagination[20]. While they are occurring, our waking memory of dreams is that we were conscious of them at the time, so it is difficult to support a claim that we were not conscious of a dream while we are dreaming it.

Can we say we are conscious of anything is we do not act observably when the state of the thing changes? Suppose we are totally paralyzed, but wide awake. We would be completely conscious of our surroundings and of events around us, but could not show our awareness to anyone else, any more than could a bronze statue. A leading article in the July 25 2019 issue of Nature (Sohn, 2019) suggests that it is possible to detect consciousness through the observation of neural activity. If the parallel track model of perceptual control is valid, the situation is less clear-cut, as only the puzzle-solving processes of the Predictive Coding track using imagination can be fairly attributed to consciousness. The control actions of the non-conscious reorganized perceptual control hierarchy clearly cannot.

Sohn includes as an example the case of an unfortunate young woman who suffered a brain injury in a car accident. "*She could open her eyes and exhibited cycles of sleep and wakefulness but did not respond to commands or show signs of voluntary movement*." Owen et al. (2006). However, when examined in fMRI, and asked to imagine playing tennis or walking through her house, her brain images of neural activity were very similar to those of a healthy volunteer, and different between the two kinds of situation. It is hard to avoid the conclusion that she was consciously imagining the two different activities. Her situation, then, would have been very little different from normal dreaming, conscious but immobile.

20. Not all dreams necessarily involve sensory perceptions, as I can attest from one of my own. I had been deeply immersed that day in the construction of a viable written constitution for a Canada-wide group, and my dream consisted of the wording for such a fundamental law, totally absurd when exposed to the light of the next day, but logical within the context of the dream. Forty or fifty years later, I can still remember some of it, but whether it helped in the next day's deliberations, I cannot say. I can say that the dream did actually contain a visual component, since in it I read the words of the fundamental law off a parchment scroll. Even now I remember that it started with "Whereas" and contained some (in the light of day absurd) wording about a ski-jump that crossed over a provincial boundary.

Chapter III.5. Belonging in a Community

Collective control exists when the actions of more than one controller influence some environmental variable in the course of the different controllers controlling their own perceptions. The environmental variable is known as the Collective Corresponding Environmental Variable CCEV, which may be tangible or abstract.

To "accept" a situation is to refrain from attempting to change it. In other words, if you control the perception of the situation at all, the current perceptual value is within your current tolerance zone around its reference value for you. If you accept as your own reference value the perceived value of a CCEV, you are conforming to the "behavioural norms" of the controlling collective, and you will not act so as to change its value. Since there is no direct mechanism in hierarchical PCT for perceptual values to replace their own reference values, either this does not happen, or it happens in an indirect manner. This indirect route to acceptance of the apparent reference values of the collective is the central topic we explore in this Chapter.

We return to the level at which McClelland was talking in the extended quote near the start of Chapter II.4. That quote begins with

> *The kinds of activities described as work in everyday language are activities that create stable feedback paths in a shared environment for the benefit of other people. The word is also commonly used to refer to the kinds of activities that maintain these feedback paths in place. Thus, work activities produce some kind of environmental stabilization, the creation of some atenfel, molenfel, or molenex, which can then be used in controlling other perceptions.*

and ends with

> *In some kinds of work, people* maintain *feedback paths rather than* creating *them*[21]*. People doing this work take the existence of certain feedback paths as perceptions to be controlled and then seek to protect them against the ongoing effects of disturbances. The janitor cleaning a building, the systems engineer fixing software bugs, the emergency responder driving an ambulance, or the baby's caretaker changing a diaper, all work to maintain feedback paths for others. Thus, the feedback paths in our shared environment depend on constant human attention and effort to do the work necessary to keep them stable. Without continual work, a humanly structured environment begins to crumble over time, like ghost towns or ancient ruins. The environments that most people live in are filled with feedback paths, both physical objects and routine actions, that have been shaped and maintained by human work.*

The relationship between this and the Prigogine concept of sufficient complexity to allow the construction and maintenance of structure (Section II.4.6) should be clear. In the quote, McClelland also refers to manager and worker Roles in abstract cognitive work. I think of them as performing Roles functionally analogous to the template-based processes that in the micro-world allow complex structures to be built and maintained from succinct descriptions. They create and disseminate plans, for example,

21. Emphasis mine. This point is important when we talk about ownership, money, trade, and energy in Chapters III.8 through III.10, especially Section II.10.2.

using the information available to them about the state of the part of the world with which their current Roles are concerned. In their playing of the Role, they are likely to use a reference state provided from Roles elsewhere in their organization, or as persons by the collective actions of their peers.

In Chapter IV.3 we will see some few of these "abstract" workers, the persons playing manager Roles at various levels, as comparator nodes in organizations patterned as hierarchical control systems, but they also can perform other Roles in interaction networks outside the organization (and in the informal networks that form within most formal organizations. Whatever their Roles, they allow the maintainers to have reference patterns for their work on the physical and social infrastructure that allows and requires individuals to control certain perceptions relevant to their Roles. In this Chapter we continue where we left off in following McClelland's ideas on controlled perceptions as stabilities usable as atenfels for various purposes of perceptual control.

III.5.1 Roles and Belonging

We are coming to the conclusion that a community, large or small, is described or determined by the Roles and their associated Protocols that are used within it. The Protocols are links in a network in which the Roles are nodes. Between any two Roles, there may be several Protocols, but every Protocol links only those specific Roles. To belong fully to the community is to be able to play the Roles using the already collectively controlled Protocols. When these are not properly played, as when a new person tries to join the community, that person will need to reorganize to avoid being rattled by the resulting disturbances caused by the unexpected actions of the existing members of the community.

One interacts with someone from "The other side of the tracks" far less frequently than one does with members of the local community on this side of the tracks, but that is far from the only reason why groups might exist within which the pairwise interactions are more frequent than between members of different groups. Simple geographical distance is one such reason, but there are many others. Members of a rugby section of a sports club, for example, will interact more with each other in the physical environment of the club in the context of rugby than with tennis players in the same club.

The situations that occur in rugby have much in common from one rugby club to another, and many of these situations occur only in competition, when the interactions are with members of another rugby club. A whole set of interlocking protocols should be expected to be the same across all rugby clubs, though their implementation might differ among clubs (one club might be in Samoa, another in Germany, for example, in which case the language used to implement a protocol is unlikely to be the same in both clubs, even though the protocol may be identical). The generic "rugby club" names a "culture", a set of protocols unique to the members of that culture regardless of the underlying "language" in which the protocols are performed, or even despite rugby being only one of several sports played at that club.

When you have sets of interacting pairs in which each set member can interact pairwise with many others, you have a network. In fact, considering Figure III.5.1, you have not just one, but a considerable number of protocol networks that interlock in the sense that a you might belong to several of them, such as being a family member, belonging to a church, working at a particular job, being a member of a sports club, and so forth. These different roles involve the use of different sets of protocols, and a person who can play those different roles can be said to be "polycultural", as most of us must become, once the circle of people with whom we interact becomes larger than our immediate family circle.

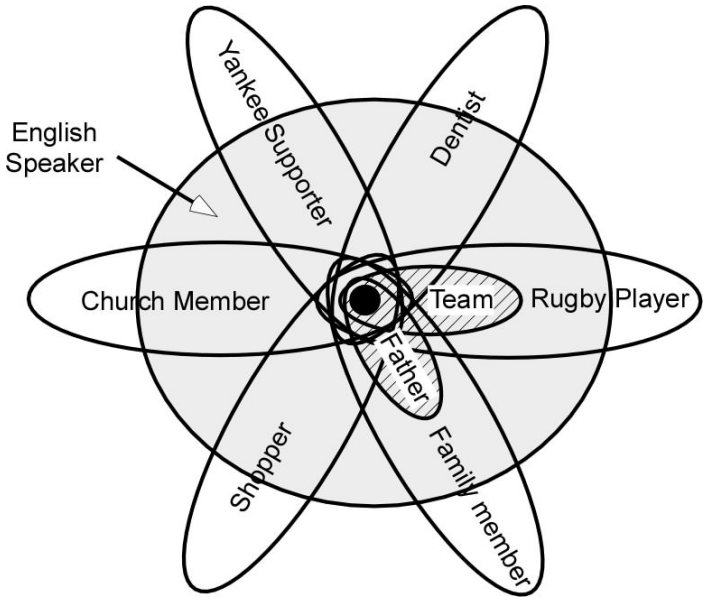


Figure III.5.1. A few of the roles a particular man might be able to play at different times. Each role gives him a set of protocols he could use when playing that role. Shaded areas indicate refinements of the larger role. For example, to belong to a particular team adds some protocols that he could use in addition to those available as just a rugby player.

Each role provides a person with a particular set of protocols that he or she might use to control certain perceptions when in that role. For example, as a Dentist she might frequently say "Open Wide", something she would be unlikely to say in her Roles as a church member or as a shopper. On the other hand, not all the protocols used by a person will be different in the different roles. Underlying them will be a common base of protocols the person uses in many different roles, collectively labelled "English Speaker" in Figure III.5.1. Each role has its own set of protocols at different levels of support, very much as in the normal control hierarchy the controlled perceptions are linked in a network of mutual support, control of perceptions at one level supporting control of those at the level above.

In his chapter in LCS IV, Nevin points out that seemingly information-free interchanges such as "Good Morning, How are you?", "I'm fine thanks. And you?" allow the conversational partners to calibrate various feature-level speech recognition systems, thereby enhancing the likelihood that subsequent interchanges will be easily understood. I argue here that they do more: they allow the partners to assign each other to groups or roles.

For example, one person might utter the greeting with an American accent or simply say "Hi", the other with a British accent might use the full "Good Morning. How are you today?". Those roles are likely to be associated in each partner's perceptual apparatus with a large variety of other perceptions that a Briton might think of as "being American", and vice-versa. But both would associate the other as belonging to a category of "persons able to conduct a conversation in English" even though the "English" they then expect to hear might need a little translation. As someone[22] said about Britain and the USA: "*Two nations divided by a common language*", though, at least until the advent of national television,

22. Different forms of the quote are ascribed variously to Oscar Wilde, Bernard Shaw and Winston Churchill.

followed by the mixing of soldiers from different places in World War II, one might with more force have said it about different regions of Great Britain such as Somerset[23] and Yorkshire.

III.5.2 Do Places have Roles?

We have treated a Role as a part actively played by a person, but just as a personally friendly actor can perform the Role of a scheming villain on stage or in a movie studio, he or she would not ordinarily do so in the middle of a city intersection or at a table in a restaurant. The perceptions they controlled by the "act of acting" would not be influenced the same way there as they would be on a stage where people playing the Role of "audience member" would sit and watch the performance.

All interactions among people must be transmitted through the environment, and therefore so must all interactions between Roles. Not all Role pairs play complementary parts. In a "Shop" place, a person playing the Cashier Role may interact with a person playing a Customer, but not with another simultaneously playing the Cashier Role. As Cashier, the person playing that role interacts only with a person playing the Customer Role, though the Cashier *person* may interact with the Customer *person* or with the other Cashier *person*. A Cashier-Customer interaction is unlikely to occur except in a place where goods or services are customarily sold, a place we might say is playing the Role of "Shop", even though it might not ordinarily do so, as in a weekly market.

To make an analogy with basic language syntax as taught in schools, the Place playing the Shop Role is like a Verb, which describes how two objects represented by nouns interact. Any verb may link a wide variety of actors and patients (things or people acted upon), but that variety is restricted to specific semantic domains. It is a stretch to imagine a way in which "candelabra", "ride" and "butter" could comfortably fit into a meaningful three word phrase. Likewise with Places. Each Place has restrictions on what Roles may interact within it, and those restrictions define the Place as part of a collectively controlled syntax of interactions among living control systems.

Places restrict more than the Roles ordinarily played within them. Collective control can also restrict the means of performing protocol interactions between Roles playable within them. Restriction, however, is not the only function of collective control in connection with places and their Roles. A Place can function as a tool, easing or enabling behaviour that was not truly available to control a Virtual Perception of a Collective Controller with many members. Indeed a Place can be *designed* as a tool for collective control, as might be an arena, a stadium, or a playhouse.

Let us look a little closer at the concept of a "tool". In Section II.3.9 I said:

> *A tool is designed and shaped to serve a purpose. "To serve a purpose" is an everyday way of saying "to enhance the control of a particular kind of perception". Although a hammer can be used as a pointer, a paperweight, or a bludgeon, in its role as a tool it is designed to make driving nails into wood easier than would be the case without the hammer. Controlled perceptions that include the relationship between a nail and some wood can often include the tool-atenfel of the hammer in*

23. While playing cricket at a village in Somerset around 1970, I noticed a small dog of an indeterminate breed lying on the playing field side of a low boundary fence. I asked a local who seemed to have a connection with the dog "What kind of a dog is that". His answer could be transcribed as "*Her be a Sooner Hound, her be. Her be sooner on that side of the fence than this*" ("this" being pronounced something like "thee is"). The difference between his "English" and mine was in all of phonetics, intonation, word choice and syntax, though he told an intentional joke I could understand.

their environmental feedback path.

In this paragraph, I use "tool" to refer to something *designed* to serve a purpose as an atenfel for control of a perception imagined by the designer. In everyday language, however, we often treat "tool" as though it meant much the same as any entity that provided an atenfel, whether or not it was designed for that purpose. We say "I used the rock ledge I found as a viewing seat" and the like, referring to something not designed, or as something designed to help control of a quite different perception.

When we talk about Roles and belonging, the title of the previous section, the same applies to Places. A member of cathedral choir is very unlikely to belong to a Muslim, Hindu, or Buddhist group, or to go to a mosque in order to sing. Non-Christian people may visit that same cathedral, but not in order to sing hymns that praise God along with other members of that choir. They would not perceive themselves or be perceived by the choristers as belonging, no matter how much they enjoyed the music.

That same Hindu might sing on a secular stage along with the people who form the cathedral choir, but that choir would not be the cathedral choir. The purpose of their singing in that Place would not be the glorification of a Christian God, but the production of music so that they might perceive enjoyment in their hearers. Place matters.

Places such as cathedrals or mosques are designed for purpose, just as much as is a screwdriver or an electron microscope. A grocery is a Place where someone might go to buy foods that are not easily found elsewhere than in the "grocery" category of Place. Of course, just as most objects are atenexes offering many atenfels other than those they are designed to offer, so many large shops, "supermarkets", are Places designed to admit to the use of a variety of Roles relating that use the PCT "Trade" motif that we will discuss in Chapter III.8.

Designed Places have characteristics of Tools, in that they allow a person, a collective, or a Role to control certain particular perceptions better or more easily than they could do elsewhere. A stadium allows many people to interact with each other while being "entertained" by other people who control perceptions of "being entertaining". The same is true of auditoriums, arenas, concert halls, and the like, which are distinguished only by designs that make them better suited for the "entertaining" Roles played by one kind of performer than by another. A stadium is seldom the best kind of Place to listen to Jazz or a Symphony, and a football game cannot be watched in an auditorium except by the use of another designed tool, television. Places have collectively controlled linking Roles — "verbs" — that accept only a certain set of Roles that they can link.

III.5.3 Protocol failure III: Reorganization to the Collective

When we discussed Marcel among the J's, we discussed problems Marcel might have when he tried to interact with individuals such as Jack or Julie or Jim. The "J" region is a Place in which Marcel could not use his language atenfels for purposes such as asking for a glass of water. Marcel used his acoustic feature set differently from the J's, which made it hard for him to understand their words, and vice-versa; he used words that had no meaning for the J's, and behaved in ways that they could not interpret in terms of the perceptions he was controlling. His protocol displays did not work for the J's and theirs did not work for him.

If Marcel interacted frequently with John, both of them might reorganize so that John could make sense of Marcel's strange sounds and behaviours, and Marcel might likewise learn some of John's protocol methods and components. They might develop a pidgin language. However, if Marcel then interacts with other J's, this pidgin will be of not much more use than was his original language.

If Jack, Janice, John, and Jake all control their features, syncons, trajectories and other protocol-related perceptions similarly, to similar reference values, they are participants in an interlocking network of Giant Virtual Controllers for all these things. The structure of Giant Virtual Controllers can reorganize, but it is likely to do so slowly, because if one individual shifts the way she does things, the others will be more likely to correct her than to reorganize themselves all together to conform to her "New Way". Conservatism is built into the Giant Virtual Controller — though as with individual hierarchies, the Giant Virtual Control network must be susceptible to "The Bomb in the Hierarchy" (Section 6.5).

Seen in this light, apart from his introductory period with John, Marcel has only one interaction partner among the J's, a partner that is not an individual, but the Giant Virtual Control hierarchy we might call simply "JO". In contrast to Marcel's probable experience when working only with John, JO will not reorganize to accommodate his different ways of talking and acting. If his protocols are to work with JO in the person of any random member of the J's, Marcel must do all the reorganization. But his reorganization is unlikely ever to make him sound and act like someone brought up in the J family, because the redundancies in the multi-layered structure of protocols ensures that most of the time he will get what he wants before reorganization has brought his lower-level protocols to perfection.

A CCEV that is defined by a community of controllers need not be a physical object; indeed, when we are talking about culture or language it almost always will be something much less tangible, such as the pronunciation of a word or the "correct" way to address one's boss.

However intangible, the environmental correlate (CEV) of whatever perception each individual controls is still a function of patterns received through the senses in the present and historically, and may be perceptible to another observer who has the appropriate perceptual function. At a particular stage in a protocol used by the J family, the CCEV being influenced will be perceived by any JO, but not necessarily by Marcel.

As Marcel learns to make himself understood by the J family members, he is shifting his reference values at many levels of perceptual control. This may seem a bit strange, since in PCT, reference values are generally thought of as the target for movement of a perceptual variable. But now we are talking as though Marcel's reference values were directly perceived and influenced by members of the J family, which is impossible. What is not impossible is that Marcel changes his own reference values in the process of correcting perceptual error at a higher level, such as a perception of being understood and accepted by any JO.

The disturbance implicit in not being understood on some occasion either is successfully corrected by Marcel trying different ways of saying the same thing at some level of the linguistic control hierarchy (changing the words used, changing the pitch trajectory, changing the situational context by using hand gestures, and so forth), or is not corrected. The disturbance are stochastic, as are the corrective actions in throwing stones to move the puck to a specific point in Section III.1.2ff. Now the target for the puck is, for Marcel, a perception that he is usually well understood, and his stochastic actions are changes in his reference values for lower-level perceptual variables.

III.5.4 Protocol, Ritual, and Collective Control

When we discussed the relationship between ritual and protocol in Section II.14.6, we had not developed the concept of Collective Control very far. Now we treat the collective control of ritual form and protocol function.

A "ritual" is a prescribed form of protocol that, as we suggested earlier, exists so that "witnesses" perceive that some collectively controlled property of at least one of the actors has changed. There is a

ritual for a Catholic Mass, for swearing an oath in court, for marrying, and so forth. Of course, the "prescribed form" is prescribed only at one or two levels of perception; no two people perform precisely the same actions when performing or attending Mass, but if the Mass is done correctly, certain perceptions must come close to prescribed reference values, which are collectively controlled within the relevant culture. If the J family (Section III.3.5) is Catholic, any one of them will perceive something consequent on the Mass being performed, but Marcel might not perceive anything similar.

Whereas a formal ritual admits no variation at the perceptual level that defines it for the witnesses, variation is at the heart of a protocol. The partners must act to control all the perceptions of each other that are needed to ensure that the continuer does whatever corrects the error in the initiator's primary controlled perception. Control of many different perceptions may be required, and each of the supporting control loops conforms to the PCT mantra "Many means to the same end".

However, even an interactive protocol with all its possibilities for variation may have some aspects of ritual. A simulated warlike Maori greeting to a visiting stranger is quite different from a greeting offered by an English householder, which is different again from that of an office receptionist greeting a visitor. If any of them used a form belonging to one of the other cultures, the visitor would, at the very least, be rather taken aback. Nevertheless, in all cases, the intent of the greeting is to welcome the visitor and to proceed to the business of the visit. The ritual component of the protocol is developed through collective control.

Collective control cannot occur unless there is something in the environment — a CCEV — to which the perceptions of different control systems can nearly correspond. In the stories of Len, Sophie, and Dan and their descendants, the protocols they use were reorganized in each individual in the usual way. If control works well, rapid reorganization is unlikely, but if it does not, reorganization usually proceeds apace until it does.

People can perceive many different things at the same time, using many distinct perceptual functions. A protocol initiator we call Sam, can, for example, separately perceive his own actions together with those of the continuer Tim, when the two of them interact in the cooperative way being developed through the co-reorganization. Using these "Observer-type" perceptions, which are not themselves involved in the execution of the protocol, Sam is likely therefore to form a perception of the pattern of the developing protocol. The process is similar in principle to the development of the "chair" as opposed to "chair part" perception we discussed in Section 5.3 on Perceptual Complexes.

Sam may be able to use that pattern, including his own and Tim's action sequences together, as a reference for a new control loop that controls a perception of the ongoing protocol execution. If he thereby gets from Tim what he wanted to perceive, his "protocol perceptual function", together with a reference for its "correct" output, will be unlikely to change through reorganization. Tim, likewise, will be likely to develop a perception of the protocol from his point of view. Each of them will be able to control for perceiving both of them to be executing the protocol "properly"; if in a particular instance, either perceives the other as not executing the protocol properly, he may act to correct the execution. The protocol form becomes an abstract CCEV, collectively influenced by the two of them.

As discussed above, control cannot work well if the two parties have different references for the protocol form, but if they both are controlling for it to work well and it doesn't, they must reorganize so that their references for the protocol form come to agreement, at least within tolerance bounds. If they are controlling for being perceived as belonging to a specific cultural group their common reference values must converge to those of the group's Giant Virtual Controller for the form of that protocol.

If Sam's actions to control his perceptions do not influence Tim's CEV (for any controlled perception, including a protocol) in much the same way as they would influence Sam's own CEV if roles were

reversed, there can be no sense of collective control. What is controlled collectively is then a construct visible only to an analyst, a CCEV defined by a pattern of commonality between the two CEVs, as suggested in Figure III.5.2, which shows a "parallel coordinates" representation of the relative influences of the different features on Sam's and Tim's controlled perceptions (and thus their CEVs).

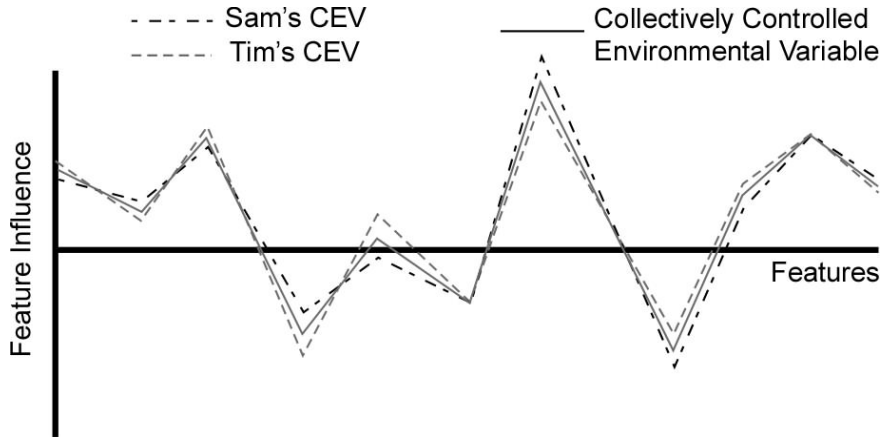


Figure III.5.2 Collective control may not be of exactly the environmental variable controlled by either party, though they all may perceive themselves to be controlling their perception of the same CEV. In this "parallel coordinates" view of the influence of the features on the perception, both CEVs depend on the same set of features, and the influences of the different features on Sam's and Tim's controlled perceptions may be quite similar, but they are unlikely to be identical. The Corresponding Environmental Variable that to an observer seems to be controlled (the CCEV) is subject to influences from each feature something like the average influence of the feature on the CEV of the individual controllers.

We have considered two ways someone entering a new culture may learn the appropriate protocols. Protocols may be learned by reorganization until "it just works", or they may be learned by observing other people employing them. A third way is to be overtly corrected when one uses it in a way the partner or a bystander (either could be "the teacher") perceives to be wrong and displays in what way it is wrong. For this to happen, at least the learner and the teacher must each have some perception with a reference value for what constitutes the protocol, and their two references must differ. The difference between reference values leads to the "erroneous" pattern of actions by the learner.

III.5.5 Rights, Customs, Obligations

One class of abstract CCEV is that of "rights". In the cartoon of Figure III.5.4 below, the newcomer has no "right" to ask the older graduate student how her research is going. One understands that this is the case not only as part of the greeting protocol, but in general. There is no law against asking, but it just "isn't done". If Cal is controlling for knowing the state of Beth's research, just asking her is not an atenfel admissible in the protocol forms that are CCEVs in the graduate student culture. "Not admissible" means that it would be outside the tolerance zone of most members of the Giant Virtual Controller who observed it. Another graduate student who observed a fellow student asking such a question would probably act to correct the error.

Having a right to do something is an example of one of McClelland's abstract stabilized variables (see the quoted passage in Section III.5.1 on Infrastructure). It is the CCEV of some controlled virtual perception. People perceive that you have the right, and because they do, you in practice do have the

right. If you act using the atenfel provided by the right, you will not be rattled by unexpected disturbances, such as in the way Adam opposed Cal's questioning Beth about her research. Different cultures have different rights.

Customs and obligations are CCEVs very similar to rights, but in our language we distinguish them. Let us see how they differ and how all of them are different from laws.

Figure III.5.3 shows the same configuration of reference values and tolerance limits as Figure III.2.2, but instead of suggesting the forces applied by the different control systems, it points to the areas over which everyone (except the stranger) is satisfied. In the left panel, there is no such area, whereas in the right panel there is a very small area in which all the tolerance zones (again except that of the stranger) overlap. This small area could be thought of as an idealisation of whatever they are all trying to control; for all of them there is no error in the controlled perception, but if the CCEV moved even slightly, some of them would experience error and would act to rectify the situation.

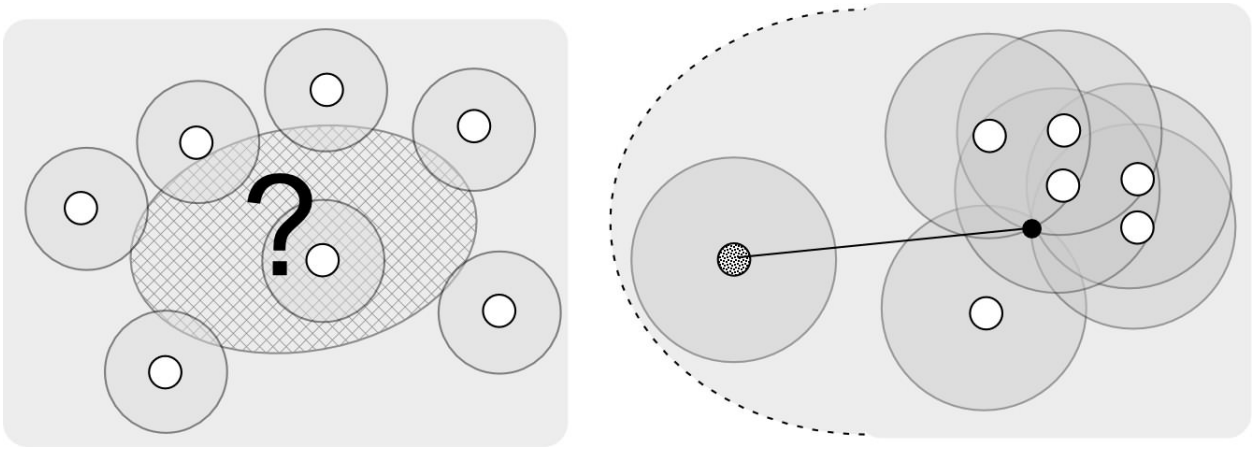


Figure III.5.3 Tolerance zones and ideals. In the left panel, there can be no agreement as to where the CCEV that they are all influencing should be, whereas in the right panel there is a tiny region where all except the stranger accept as being correct. If the CCEV moved even a small distance from the area of tolerance overlap, perhaps as a result of the stranger's action, some of the controllers would perceive it to be "wrong" and would act to bring it back.

When a CCEV has a very tight range of permitted variation, the virtual reference for it approaches a platonic ideal. As discussed earlier, a platonic ideal is a form, such as a circle, that can never be exactly produced, but which can be defined as a reference pattern (a profile) from which deviations can be perceived. Each individual may have a different perception of this reference form, but the Giant Virtual Controller (GVC) will act to correct deviations from the virtual reference value when individuals act to move the virtual controller's perception of the CCEV outside the virtual tolerance zone. If, however, control is stochastic, whether any particular deviation will be corrected depends on which member or members of the GVC perceived the transgression. For some, the deviation will be within their tolerance zone, but for others, it will not, and the disturbance to their controlled perception will need to be countered by action.

When each individual has a different reference value for a collectively controlled artifact, acts that would move the corresponding CCEV are seen by some as violations of convention. The offending action "just isn't done", but nobody can say why, except perhaps that "it is bad manners to …" (… put your feet on the dining table, jump in front of the queue to get on a bus, wear a tuxedo to a beach party or beach clothes to a formal reception).

A collectively controlled artifact might include a required action, such as that a person should say "Thank you" after being given something or "Sorry" after inadvertently disturbing someone's controlled perception and becoming aware of having done so, or should bow to the correct degreee on newly meeting someone. Failure to perform required actions correctly can be as much "bad manners" as performing some "wrong" action.

Different groups have different definitions of "bad manners", but whatever the definition, a person whose actions are outside the "good manners" macrostate will be perceived as "not really one of us" to some degree. As an extreme example, a gang member who fails to murder when asked to do so may face considerable disturbances to some of his controlled perceptions; less extremely, a schoolgirl who befriends a chosen victim of a friendship group may be excluded from that friendship group. What most people would perceive to be "good manners" is perceived by such groups as "bad manners", and might reduce the person's fuzzy perceived membership in the group well below 1.0. This kind of convention is a custom. Some particular person in talking to a particular other might have the "right" to fail to say "Thank you", but might ordinarily do so nevertheless.

Just as with Taylor and Taylor's theory of phonetic symbolism (Section II.12.9), if a particular pattern of behaviour in a certain context happens more often than some other pattern that might seem equally appropriate *a priori*, the more frequent pattern may be become an identifiable perception that can be controlled. "*Clothes maketh the man*". A century and a half ago, a well-dressed English "gentleman" might wear a silk top hat to go to a formal occasion, whereas a Moroccan of equal status might wear an elegant fez, even to the same occasion in England. If the two exchanged headgear for such occasions, each would be perceived as ridiculous, comments would be made, and the offender might even be barred from the occasion, though if the Moroccan also wore English formal clothes, then he might instead be perceived as ridiculous if he wore a fez.

Reorganization would probably happen so that the "gentleman" would use the "correct" headgear to the next such occasion. Yet the English gentleman of that era might well wear a fez in the comfort of his own home when entertaining a friend or two, though not when wearing white-tie formal attire. And a sufficiently high-ranking English Lord might be able to wear a fez without being corrected at events where such attire would be forbidden to a lesser mortal.

There would have been no formal rule stating what headgear was required for attending a formal occasion, and it is unlikely that the youth who became the top-hatted or fezzed gentleman would have been specifically instructed as to when such headgear was right and when it was wrong. The first time he was invited to such an occasion, he might ask his elders what he should wear, and might accept the answer as a reference value for dress in similar contexts, as Powers suggested in his proposal for associative memory as the reference input function of a control unit (Powers, 2005). Since many other people control perceptions of appropriate dress for such occasions, the dress format is collectively controlled.

The profile that determines the context in which a silk top hat is appropriate is not well defined by the youth's first invitation, and he is very likely to have different tolerance boundaries on the range of "similar" contexts than do others. Indeed, the boundaries are likely to differ among all the "gentlemen", as was the definition a century ago of whether one belonged to the "gentleman" class and even has the right to wear a "topper" at a particular event. Accordingly, even if the youth is quite definitely a "gentleman" (regardless of his boorish behaviour), there will be occasions when some individuals have reference values that the occasion is, and some that it is not, suitable for a top hat. Among these would be that the youth is or is not yet perceived by himself or by others to be an adult.

Collective control of custom has fuzzy boundaries. It is soft at the edges and there will be occasions for which a top hat is neither required nor wrongly over-dressy, but is permissible. A top hat worn to a

party by the scion of an upper-class family might be perceived as play-acting or as a joke when the youth is ten, but a failure to wear it might equally be perceived as rebellion or as a joke when the youth is twenty. Both cases suggest to others that the youth is claiming membership in a group to which he is not otherwise entitled to belong.

We have been talking about some customs of a century or more ago in Eurocentric cultures, and today's customs are different. Customs drift, partly because of the fuzzy boundaries. Only when most of the people encountered by the youth of a century ago control for the same value of the CCEV will the custom be clear. If there are similar contexts in which some people have a reference for wearing a bowler hat or being bareheaded, the youth is less likely to be subject to unwelcome comment for failing to wear a silk top hat, and is less likely to reorganize to wear one in future contexts similar to the one in which he successfully failed to wear one.

On the other hand, customs can become solidified into obligations or even codified into laws, which have much sharper boundaries and for which there are associated CCEVs, such as the "right" of a defined set of people (e.g. policemen, judges, Church elders) to impose sanctions in the form of disturbing a controlled perception in the offender (such as by levying a fine) or removing some atenfels that enable the offender to control some perceptions (such as by imposing a jail term).

Many laws seem to have no rationale other than to give selected people the right to enforce a custom. People in a position to make the law control the corresponding CCEV with small tolerance zones and high gain, so that life is made difficult for people with different reference values for the CCEV. In one country, perhaps a woman must veil her face in public, in another perhaps she must not. If either practice were intrinsically important to allowing other people to control their perceptions, the opposite one could never have become a custom, let alone a custom controlled at high gain and low tolerance by those with a right to make laws.

Games have precise rules, descriptions of what may and may not be done, and specify the consequences of well-defined events, such as (in soccer) the ball crossing the goal line within the rectangle defined by the goal posts and cross-bar. A rule defines who wins and who loses the game. Most game rules are arranged to engender conflict while bounding the effects of that conflict. In soccer, it would be easy to control the ball by shooting an opponent but that action is not allowed within the game.

There are no exceptions to game rules (other than those the referee does not see), though in many games the CCEV for a rule has fuzzy tolerance bounds. In the absence of a referee, one team in an informal soccer game may perceive a tackle as a foul, while the other team perceives it as legitimate. Their tolerance bounds for what "we" and "they" may legitimately do are not the same, although they may have the same platonic ideal value for the CCEV that defines a tackle.

Game rules are a collectively controlled perception of a particular kind. They may be agreed for a particular occasion between the opposing players on the game site, or the players may all control for recognizing a particular "authority" as having the right to specify them, after which, in a formal game they control collectively for recognizing an "umpire" or "referee" as having the right to determine whether a particular action uses an atenfel within the rules of the game. The referee's rights are collectively controlled in the same way as those of a policeman, or better, a judge.

Obligations are a particular form of custom, not unlike the continuer's role in a protocol. The virtual controller disturbs some perception in the person in such a way that the person acts to fulfil the obligation. Just as the initiator in a protocol "obliges" the continuer if the continuer controls for accepting the protocol, so the virtual controller "obliges" the person because failure to fulfil the obligation will disturb some a perception of the "obligation" in the virtual controller, resulting in action that might increase the non-obliging person's reorganization rate.

To put it in a more concrete form, little Johnny wants a toy that older sister Susie doesn't seem to be using, and says "Please could I have the toy". Susie withholds it, and Mama says: "Susie, Johnny asked nicely and you aren't using it. Please give it to him." In that family, if you aren't using something and someone else asks for it using the "Please" formula, you are obliged to give it, or at least allow the asker to have it. The "correction" could come from anyone, Mama, Papa, older sister, even a family friend, all of whom could be members of the relevant Giant Virtual Controller.

Among individuals more mature than little Johnny, perhaps the controlled perception is of belonging to a particular culture: "*When in Rome, do as the Romans do*". Perhaps it is a perception of how "self" is perceived by others, or by oneself. Whatever the major controlled perception, failure to perform the obligation will create error in it, error that is caused by actions of the Giant Virtual Controller for which the obligation is a CCEV. Such an error can be reduced by doing whatever the obligation requires, exactly as happens for the continuer in a dyadic protocol.

We now can state the key differences among rights, customs, and obligations, all of which are the products of collective control. A right is an atenfel that the Giant Virtual Controller controls for being available to an individual, and the Giant Virtual Controller will control for perceiving other people not to impede the use of that atenfel. A custom is a manner of behaviour that is expected in particular circumstances, and the GVC will control for perceiving that behaviour, independent of what perceptions the behaviour is being used to control. An obligation is an action to reduce error in some perception related to another person or persons, and the Giant Virtual Controller controls for perceiving that error to be reduced.

It is not always true that one can exercise one's rights without causing a conflict, either internal or with other people. Conflicts of rights are the subject of endless debates on what we call "ethics". Nevertheless, collective control of rights does reduce the likelihood of conflict in any particular situation.

III.5.6 Morals and Laws

A law specifies actions that should or should not be performed, without regard to what perceptions might be controlled by those actions. If the person controls for abiding by laws, a law removes atenfels from that person's environment or requires the use of some particular atenfel, such as filing a tax return. If the person uses a prohibited atenfel or fails to perform a required action, a social Giant Virtual Controller (virtually) perceives certain people (referees, judges, police, for example) as having the Authority to punish — to disturb and to prevent control of some other perception or perceptions. The imagined punishment sets up a conflict between control of a perception that would use the prohibited atenfel and control of any perceptions for which control might be impeded by the legal authorities. We will consider the effects of laws further when we talk about Power.

Morals are different, unless there is a GVC that perceives them as representing "God's Law". If there is in that community, then the immoral event is an action used to control some perception, and anybody has the right, and possibly the obligation, to impose punishment. Outside such rigidly doctrinaire communities, morals *are* different. Violation of a law is an all or none concept, decided, if necessary, by a judge. Violation of a moral code disturbs a perception controlled by some Giant Virtual Controller for which the CCEV is influenced by the immoral act. It is usually immoral, but not illegal, to sleep with your neighbour's spouse.

Morals depend on the community group and role being played. This can sometimes cause difficulty for some people who find that the situation should not alter the ethical correctness of different actions. For example, in a boxing ring, but not on the street, it is morally acceptable for two men to hit each other hard enough to hurt, and legally permissible to act on those intentions.

To cite another example, in the late 1950s a multi-person game designed not to be open to analysis by Von Neumann and Morgenstern's (1947) Theory of Games was circulating. In this game, all information had to be open to every player. Secret deals, for example, were not permitted. The only way to win this game was for individuals openly to make alliances and then, equally openly, to betray their allies at opportune moments by making new alliances against their previous allies (just as nation states may do). Some people could not play that game effectively, because they could not alter their reference value for whatever self-image perception the betrayal disturbs, and refused to betray their allies even when it was a correct tactic in the game. The immorality of the betrayal was something they could not do or accept when someone else did it. Others, who in everyday life would never be morally able to betray a friend or go back on an agreement, played the game quite happily.

III.5.7 Authority and Rules

A convention or a moral precept is not a rule or a law. Violation of a convention occurs when someone acts in a way that other people "feel is not right" to some fuzzily measured degree. Rules and laws on the other hand, however, use language to describe specific actions that are precisely "not right" or that are required. Violation of a rule occurs when someone performs an action that contradicts another's perception of the meaning of the rule. In language more suited to PCT, person X performs an action that differs from person Y's reference value by more than Y's tolerance, where Y's reference value is Y's perception of the rule. X and Y may both use the language version of the rule, and set up their reference profiles as they perceive the rule, but their perceptions may differ. Who decides? Who is the authority — or Authority? A convention has no Authority, but a rule or a law must.

If you live in a "polite" North Atlantic society and a child abruptly says to you "Close the Window", you might answer "Say 'Please'" and not close the window. You would be counter-controlling, by failing to act to reduce the error in the child's perception of the window state. You are acting as an "Authority". If the child then says "Please close the window", you do close the window, perhaps also saying "That's better, thank you" (using one of the other possible instantiations of the "Accept" arc of the GPG; simply closing the window uses a "null" instantiation). The child has perceived you as an Authority.

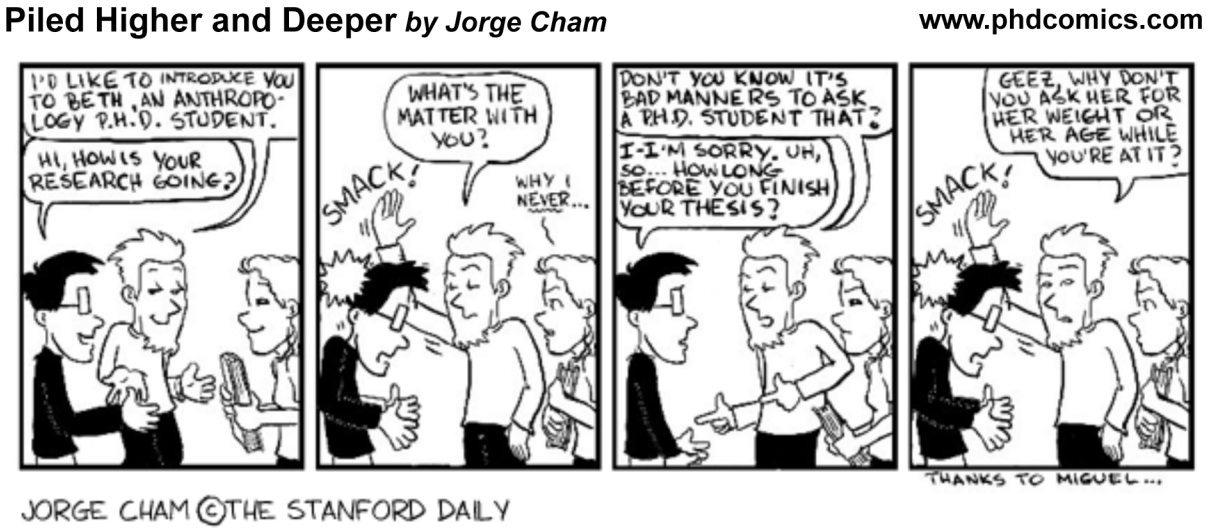
Perhaps you explain to the child that to say "Please" when asking someone to do something is to show the person that you respect their ability to refuse if they have reason to do so, whereas failure to say "Please" shows that you do not accept that they may not wish to do what you want. You are modifying the child's World Model of "*The Way the World Works*", whereas the action (or non-action) of failing to close the window and then after hearing "please", closing it, would tend to increase the child's reorganization rate. It the child reorganizes as you hope, she might say "Please" on later occasions, without being able to say why, other than that it just feels right.

Not to say "Please" on the later occasion might lead the other to perceive the child to be acting as an Authority, which in that culture would be a disturbance to a cultural CCEV, most people not perceiving most children to have the right to be Authorities in such matters. If you did perceive the child to have that right, you might not counter-control by refusing to do what the child wants.

You might add more to the child's World Model, saying that if the person perceives that you respect them, they are likely to respect you, and to do what you want even if it conflicts with what they want, whereas if they perceive that you do not respect them, they are not as likely to control for seeing you satisfied. You would gradually be initiating the child into the idea that there are levels of control in interpersonal interaction, just as there are in individual control structures, though you probably would not make that point explicitly when talking to a child.

In the cartoon of Figure III.5.4 “Authority” is exercised by “Adam” an older graduate student who corrects protocol errors made by Cal, a new graduate student being introduced to Beth, another older graduate student. In the “syncon world”, similar Authority is exercised by Rob the robot. In protocols used among people in a particular “culture” certain “roles” and protocols fit together, whereas others, that seem superficially similar, do not. “Authority” is such a role.

Authorities have collectively controlled rights that others do not have. The cartoon shows slaps administered by Adam that could not have been administered by, say, an undergraduate, or even by a professor, neither of whom would be authorized by an Authority or by collective control to use that particular protocol form as an atenfel for “correction”. Only an older member of the graduate student culture could act as an Authority in this situation without Cal objecting, because Adam has Authority according to collective control of customs and morals by the current and past graduate student body.



title: "Grad student etiquette" - originally published 2/27/1998

Figure III.5.4. Protocols appropriate in one context may not be appropriate in another, and an observing third party may induce reorganization in a newcomer to the group. (With permission www.phdcomics.com)

Although “Adam” in the cartoon acts in the role of an authority, Beth also shows disapproval of Cal’s form of the greeting protocol. Both together are exerting collective control. One might expect that as Cal meets other graduate students, they, too would have reference values for the greeting protocol form much like those of Adam and Beth. Together they constitute a “Giant Virtual Controller” of the “Being introduced to a fellow student” protocol form, and this virtual person acts as a rather strong Authority for the idealized form of the protocol.

If Cal continues to use his initial reference value for the form of the greeting protocol when meeting other students for the first time, he will always fail to reduce the error in his controlled perception of being accepted into the graduate student society. Instead, he will probably reorganize to change the profile of his reference values toward that of the “Authority”. In this case, no one person has “Authority”, and all may act as though they do.

The context matters. In the cartoon, Cal’s reference form for a greeting protocol on being introduced includes an enquiry into the welfare of the person to whom he is being introduced. This might also be appropriate in the graduate student context, but apparently not if the welfare in question is the progress of

research. It is a feature of the protocol form that both the older participants in the introduction control for with little tolerance.

All of these examples illustrate that people control their perceptions of the way the parties in a protocol interaction should execute the protocol, and that this control gives the protocol the status of an artifact, the abstract CCEV of the "Giant Virtual Controller" that controls a virtual perception of a platonic ideal "Introduction" protocol.

"Authority" is a perception, not a phenomenon. If I recognize you as an authority for some purpose, you *are* an authority. If I don't, you aren't. If I perceive you have the Authority to take me somewhere I do not want to go, I may cease controlling my perception of my location. I would not stop controlling my location perception if I thought I was being kidnapped by someone without the Authority that I may perceive a policeman to have.

The same is true for modifications of my World Model. Suppose I perceive you to be an authority on, say, the historical price of milk, and you tell me the price of milk in 1847 was 3 cents per gallon, then I will perceive the combination "1847-milk-3¢/gal" as an association I can use in control of other perceptions should the occasion arise. If in the future for some reason I perceive the combination "1847" and "3¢", I may momentarily imagine "milk" either as a word or as a sensory (taste or vision) image and not know why I do.

The word "Authority" is used not only to specify a role, but also may be used to specify a perceived ability to prescribe rules or laws. An Authority *has* Authority. A perception of the Authority's ability to set rules is controlled by all who might control perceptions using atenfels that require the described or proscribed actions. If most of them control with a reference for the Authority's Authority to exist, the Authority's Authority becomes a collectively controlled perception. If you perceive the Authority to be legitimate, you may object if someone does something against the rules the Authority prescribes.

The Authority to create rules is the ability to say what atenfels must be or may not be used in controlling certain perceptions. If you want to drive a car, Authority says you must get a licence. If you want to get a driving licence you must pass a test. If you want to take the test, you must fill out a form, and so forth. To actually drive the car, you must perform a series of actions that sometimes seem like negotiating a maze (Figure III.5.5). Of course, it is possible to drive a car without having a licence, as suggested by the dashed "short-circuit" curve. A person who does this either is in conflict and drives because of some emergency, or does not perceive as an Authority the person or collective that produced the rule.

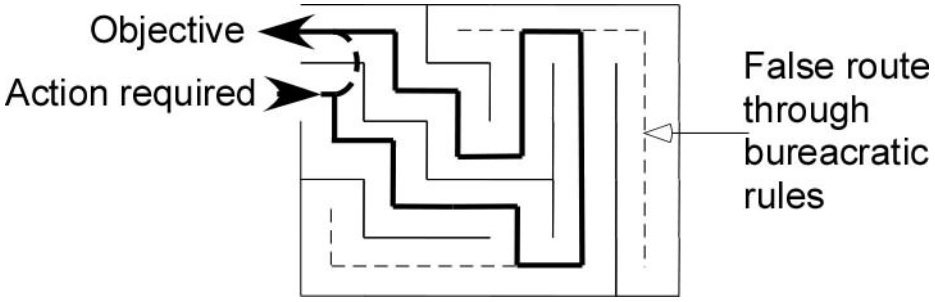


Figure III.5.5 An Authority can create rules that define atenfels that must or must not be used. In this diagram, using an atenfel is shown by crossing from one square to the next. Atenfels that may not be used are represented by solid lines, while ones that may be used are blank cell boundaries. If there is only one open exit boundary, the atenfel must be used if the objective is to be attained. The short dashed C-shaped curve shows what one might do in the absence of the rules, the heavy solid line the atenfels one must use in order to achieve the objective, while the light dashed lines show ineffective actions one might take if one misperceives some rules.

There may be others who control their perception of the potential Authority with a reference value that the ability to authorize or prohibit a particular atenfel or set of atenfels should not exist: "Who are you to tell me what to do on my own land?" Such is the case when people protest a law or judicial ruling they perceive to be "unfair". Two controllers, possibly both Giant Virtual Controllers, would then be in conflict, producing a "rod" in the grand social tensegrity structure. Sometimes, as with the person who drives without a licence, the protester may not perceive the authority as existing or as having authorized the prohibition in question, but is impeded in using the prohibited atenfels by those who do perceive it to exist. We discuss this situation in the next Section, and later further when we examine political parties in Chapter IV.1.

Reorganization happens primarily when attempts to control a perception do not work well. Since "behaviour" is the use of atenfels, there must be some mechanism whereby a rule changes the effect of the use of atenfels on perception. In the cartoon of Figure III.5.4, nothing inhibits the newcomer from asking the taboo question, but when he does ask it, a different controlled perception is disturbed by the slap administered by the "authority figure".

Authority implies deference. "Deference" is a word for the control of a perception of the rights of the Authority, with the reference that the authority has the right to define rules and to have them enforced by disturbing some perception the rule-breaker controls. An employee has given the Employer that deference, in respect of performing the job, but not necessarily in respect of the conditions under which the Employer requires the employee to work.

Deference implies the use of prescribed atenfels for control of particular perceptions — get a licence if you want to perceive yourself driving a car — or the non-use of proscribed atenfels — do not go into someone's house uninvited. Deference also implies the use of certain sets of protocols in which the one who defers allows an Authority to provide certain values that will be used as reference values for some controlled perception or other. As with any protocols, failure to execute these protocols "properly" results in continued error in some controlled perceptions, and consequently an accelerated rate of reorganization.

"Authority" as a role is different from the authority that the person occupying the role may have. The "Authority" role has different atenfels than the person has. This difference is well illustrated by a comment reported in a newspaper (Globe and Mail, March 27, 1917) on the resignation of a person I will call Dr. S from his post as Director of an institute of a university I will call "the University". Dr. S had written an opinion piece that was heavily criticized by regional politicians and by many members of the public.

Dr. S was asked to resign, which was also criticized, as an assault on academic freedom. The University Principal explained that whereas the person Dr. S had every right to publish such an opinion, as did Professor S. (a role from which Dr. S was not asked to resign), the opinion piece that was published was signed by the Director of the Institute, and that role did not have the authority to publish an opinion piece on the topic for which the Institute had been founded. Had Professor S signed it, or Dr S "writing in my personal capacity", the University would have had no problem with it. The role had very different atenfels available to it than did the person playing the role.

III.5.8 Quarantine, Nonconformity, Schism

In many, if not all communities, people infected with a transmissible disease are isolated for a while, and if the disease is dangerous or easily contracted, other people who came into contact with the infected person are also quarantined. Over extended time, it is probable that cultures that enforced this exclusion principle would be less likely to suffer from epidemics and pandemics than would cultures in which the principle of individual freedom allowed infected people and their contacts to go about their everyday business.

In "developed" countries, the "quarantine principle" is collectively controlled, but elsewhere and in earlier times, it may have been individually enforced as a side effect of non-infected people controlling for not feeling disgusted or fearful in the presence of a diseased person. We are not here concerned with the earlier individually enforced quarantine, but with quarantine as an example of a more general social phenomenon.

In Section II.14.8 we introduced the concept of "counter-control", and hypothesized that it is an outward manifestation of control of perception of a property of self-self-image, other-self-image, or both. There, we talked about counter-control against a perceived attempt by another person to make one do something. Now we are talking about "Conforming to the Community". No individual is necessarily attempting to control the actor's behaviour, though of course Collective Control by a GiantVirtual Controller is often effected by stochastic interactions with various different individuals.

Throughout history, there has often been a strain of nonconformity in some population or other. In 17th century England, for example, an entire religious movement was called "Nonconformist", because they did not conform to the requirements of the Church of England established by Henry VIII. When nonconformity is individual, a simple PCT explanation is available, but when many people form a collective controlling for a specific version of nonconformity, a Schism results, and the simple explanation apparently fails.

Quarantine almost necessarily involves conflict, either between the collective and the individual person isolated, or within the person isolated. The person ordinarily controls for being able to move freely to places freely chosen, whereas the whole point of quarantine is to deny this freedom. The conflict is unavoidable, but how it manifests itself depends on the individual and what other perceptions that person is controlling.

If the person is controlling an other-self image of not allowing themselves to be seen as bowing to being "pushed around", but of choosing actions regardless of what another person, Authority, or GVC demands, then to submit visibly to quarantine regulations would create error in that controlled perception. The actor may, however, be controlling some other perception, perhaps of a different property in their other-self-image or their self-self-image, such as their willingness to help others.

Failure to observe quarantine when required would cause error in control of such a perception, but only if the actor perceived that failure to observe quarantine would be likely to create disturbances to perception others control, such as to make them fall ill. Here we have a possibility for internal conflict between two properties of either kind of self-image: not being susceptible to being "pushed around" on the one hand, and being helpful, or at least not harmful, to others.

The conflict vanishes, however, if the actor perceives that quarantining has no effect on the likelihood of harming others if he or she fails to observe it, and that the epidemic on which the collective basing its perception of individuals being quarantined is a "hoax", an illusion that does not correspond to reality. If that is a property of "*the way the world is*" as perceived by the actor, then the control of a perception of

susceptibility to being “pushed around” with a reference value of “not” does not conflict with anything. In this instance, other-self-image is likely to be more important than self-self-image.

If one does not act as demanded by Authority or by the relevant collective controller, one is by definition a Nonconformist. In this sense, every criminal is a Nonconformist, but that is clearly not what the term usually is taken to mean. A criminal accepts that the Authority has the authority to pass laws, and acts to control perceptions of not being perceived by others as contravening those laws. If the Authority is a Giant Virtual Controller, the individual Nonconformist may not be called a criminal, but the non-conforming actions nevertheless disturb some perception or perceptions controlled by the Collective. The results may be as strongly disturbing to perceptions controlled by the non-conforming actor as are the results of being convicted of criminal behaviour.

Religious Authority is a special case. In some societies, or perhaps we should say nations, Authority is legally conferred onto the leaders of a religion. In others, a Collective Control System, rather than directly disturbing perceptions controlled by the Nonconformist, controls for a religious authority to have the right to do so according to rules they create autonomously. One can think of the Spanish Inquisition, the anti-Catholic campaigns in Tudor England other than when Queen Mary I (Bloody Mary) reigned, or various interpretations of Sharia Law imposed on some Islamic countries. In each case, the Political Authority delegated authority over some behaviours (and usually over the perceptions controlled that lead to those behaviours) to a Religious Authority.

How can an Authority control the perceptions of a potential Nonconformist? It sounds impossible on the face of it, but the problem is exactly that faced by the user of a protocol, especially when the protocol partner might be deceitful like Andre (Chapter xII.13). The Authority must observe the possible Nonconformist’s behaviour, and determine how it changes when possible controlled perceptions are disturbed. The latter is not always necessary, because acting contrary to the behaviour dictated by the Authority may be *prima facie* evidence of Nonconformity. Simply a failure to perform a ritual correctly may be sufficient, depending on the particular ritual and the particular Authority.

Nonconformity usually is not considered to be a deviant way of controlling a single perception. Instead, it is ordinarily thought of as a tendency not to do something if an Authority wishes it to be done, as we mentioned in connection with quarantine as an example near the start of this Section. Moreover, it is not just that one individual’s behaviour is, to use an antique term, “Bolshie”. There should be a group os individuals who behave similarly in their manner of nonconformism.

One nonconformist is idiosyncratically deviant. Two or more can produce a positive feedback loop that acts between separate collective controllers in the same way as we described in Chapter 9 for feedback in flip-flop perceptions. Now we see the same positive feedback of lateral inhibition in sharpening the separation between the behaviour required by the Authority and that collectively controlled by the “social deviants”. The Authority having the larger “mass” (participating members), the “deviants” are likely to change their behaviour so as to increase their deviance.

The same positive feedback effects will occur in the Authority to the extent that the small Nonconformist community, as distinct from the individuals of which it is composed, disturbs a perception the legal or Collective Authority controls as a property of that community. One possible such perception is the perception that the deviant behaviour may be serving to control a perception of “*the way the world is*” or “*the way the world works*” that differs from a corresponding perception held by the Authority. The Nonconformist believes something about the world that differs from a belief held by the Authority.

In the second half of the 16th and early17th century Britain the Church of England created by Henry VIII to facilitate his marriage to Anne Boleyn was legally the only permitted religion. To be perceived by Civil Authority as Roman Catholic might result in death. Roman Catholics were Nonconformist in the

sense we use the word here, but there were also several different sects who were collectively known as Puritan, all of them descended from the Swiss Calvinism. They were also Nonconformist, but as strongly opposed to "Papism" (Roman Catholicism) as to the Church of England. One such sect was even called "Nonconformist".

Some members of some of these sects left England for the Netherlands and then North America, to found territories that later became states where they could establish their own set of beliefs and rituals outside the legal Authority of the Church of England. For example, Puritan Law became the Authority in what became Massachusetts, and Roman Catholicism, the enemy of Puritanism, in what became Maryland. To avoid conflict due to the irreconcilable differences between these religious Authorities is at the heart of the US Constitutional "Separation of Church and State" that retains a tenuous existence even today.

There is a significant difference between the likely actions of a legal Authority and that of an Authority that is a GVC, as we discuss in Section III.5.6. A legal Authority works within a framework of laws, which have behavioural definitions with sharp toleration edges, whereas an GVC inherently has a tolerance bound with soft boundaries, controlling with greater loop gain as well as larger error signal value the larger the deviation from the ideal. Laws, however, are often written to proscribe behaviour already proscribed by a GVC, so they describe only the hard skeleton of the controlled perception, not the full fuzzy-edged perception controlled by the GVC.

We should note that even though laws are written with sharp tolerance bounds — a behaviour is or is not legal — prosecutors and judges often choose to soften those bounds based on their perception of the context of the supposed offence. In effect, they go back to the old GVC that the law was supposed to implement. They increase the dimensionality of the space within which they perceive whether the behaviour, though possibly technically illegal, was justified.

To a large extent they would be using a Collectively controlled perception of "fairness" as a reference value for their control of their own perception of the offending behaviour instead of their perception of what the law says should be their reference value for it. There is, however, another consideration, which is that the context considered by the prosecutor might include his perception of aspects of the suspect irrelevant to the behaviour for which the prosecution began. If the prosecutor perceives the suspect as being "one of us" and therefore unlikely to have behaved badly without some reason, the prosecutor is more likely to widen the tolerance bounds than if the suspect is "one of them, not one of us". In a white society, for example, a black man is perhaps more likely to be prosecuted than would be a white man who did the same thing.

An example where a prosecutor and judge did not take advantage of their potential leeway occurred a few years ago in Canada. A little girl had for many years been suffering from excruciating pain (to judge from her cries) and was in other ways also disabled. Finally her father killed her to end her suffering. Many in the community hoped they would have had the courage to do the same in his place, but the prosecutor and judge decided that the law against murder took precedence, and committed the father to a long prison term. The father was a Nonconformist according to the law, but not according to the perceptions controlled by a fairly large GVC.

Initially, as suggested by Figure III.1.9, only extremists within the GVC will tend to act against the deviant Nonconformists, but as the Nonconformist collective grows larger and more powerful, more and more of the members participate in the positive feedback loop that drives the groups apart.

We have defined what is known as a Religious Schism (or a political one, as we will discuss in connection with the "Vee Party" in Chapter IV.1). A religious Schism process produces sects within larger groupings, such as within Protestant and Catholic major christian divisions, or Sunni and Shiite divisions

of Islam, or, to back further in time, between Judaism and Christianity. Typically, to a member of one of the dividing collective controllers, the differences are very important, being enhanced by the positive feedbacks of lateral inhibition, while to outsiders they may seem quite trivial, rather than being worth shedding blood over.

Because of these same processes, we should expect to see initially rapid splitting between language dialects into different languages, and we will expect it again when we talk about cultural drift. They depend on members of collective controllers seeing particular properties of a subset of the collective as diagnostic of an important difference, as we will discuss in Chapter III.9ff. For now, it is sufficient to have introduced the concept of the Schism, so important in the backgrounds of wars civil and international.

Chapter III.6. Language and Other Intangible Artifacts

In the Prologue, we said:

> *[Dictionary] definitions do not seem to help very much when we talk as though culture and language are artifacts, so let us try another:* ***An artifact is perceptible by and susceptible to influence from humans, and exists in its current form only as the result of human perceptual control.*** *This definition is agnostic as to whether the artifact is tangible.*

In North America, a popular summer game is baseball. In England and many countries once colonized by Britain this sporting "cultural niche" is occupied by cricket. Both games together with an English game called "rounders" have a striking resemblance and perhaps an ancestral relationship to a game played as long ago as the 15th century in England, called "stoolball[24]".

When one has played one of these games and is introduced to one of the others, it is easy to make assumptions about the play that turn out to be wrong. In my own experience, coming to Canada in early high school from a cricket-playing background, I joined in a schoolyard baseball game. The first time I came to bat, on the first pitch I did what in England would be a "block", a shot intended only to stop the ball safely. In cricket, the objective of a block would be to effectively stop play and wait for the next "pitch" ("ball" in cricket), which might prove easier to hit hard. But in baseball, once you hit a ball within the quadrant in front of you, you must run in an attempt to reach at least first base. I did not know that difference between the rules of the two games, so I stood and awaited the next pitch. Everyone shouted "run", to which my response was "Why? It was not a good hit." The meeting of cultures, even closely related ones, is not always easy.

The same issue applies to related languages. When I was being taught French, I was told to beware of "false friends", words that sound like English words but mean different things. The French "librairie" is not the translation of the English "library", though both deal with places where there are books. False friends exist even between English English and US English, as the quote "*two nations divided by a common language*" suggests[25] (Section III.5.1). Separation facilitates, but does not demand, divergence. Divergence can lead to misunderstanding and even Schism, despite, as we discussed in Chapter II.2, also leading to invention. In Chapter III.7 we will consider a general mutual repulsion effect between similar but distinct homeostatically stabilized schools of thought or belief. Here we consider invention and the opposite effect, convergence.

III.6.1 Language: Catalyst for Invention

If we go back a few hundred thousand years, before our complex language was invented, our ancestors might have been pack hunters, like wolves. To coordinate the hunt, they must have developed some protocols, such as for directing some to go around the other side of the prey, or to hide in waiting, and so forth. They must have had some way of demurring or rejecting a hunting move, and a few other protocols. But they cannot have had very many different protocols, because the continuer must be able to determine

24. <https://en.wikipedia.org/wiki/Stoolball> Retrieved 2016.01.03. Stoolball is still played occasionally, at least in England. Some time around 1969 I watched a game in Kent.

25. The originator of this quip is uncertain. Some suggest Oscar Wilde, others George Bernard Shaw, while yet others suggest it was created by paraphrasing a sentiment expressed in different words by Shaw (Quote Investigator <https://quoteinvestigator.com/2016/04/03/common/> retrieved 21.12.21)

what the initiator is trying to control, and with what reference value, and without the connective relationships of language, gesture can provide relatively few distinctly discriminable possibilities.

What they may have had is music. Many theorists suggest that since there is so much similarity between the prosodic, and to some extent the relational structures of music and language, it is likely that they evolved together. This may be so, but another possibility is that music came first, perhaps very far back on the evolutionary tree, and in some species diverged into vocal and instrumental forms, each of which was able to accommodate early forms of language that lacked the relationships we use to distinguish human language from the sonic communications of other mammalian species such as our close primate relatives. Listening to two flocks of corvids, one tracking my wife and I along a wooden walkway in the Vancouver Island rain forest, the other tracking a faster group some distance behind us, it was hard not to believe that they were using a complex language. If that impression was true, language is not restricted to mammals and grey parrots (, but of course this is quite void of

The invention, if we can call it that, of the relational possibilities we attribute to language changed the situation dramatically. Using language, the initiator of a protocol could make it much easier for a continuer to know what the protocol was intended to achieve. The number of perceptions that could be controlled using protocols was extended, effectively without limits beyond those imposed by the combination of the skills and tools available to the people concerned.

Language is a catalyst for invention. Whereas before language, a flint-knapper could pass on his skill only by demonstration, after language had been invented, he could explain what he was trying to do, and why, at each stage of making a blade. A person who thought of attaching a blade to a stick so as to attack the prey at a distance could tell a partner why this might be a good idea, and how the best blade for the purpose differed from the blade best for carving meat. Another might be able to see how the spear might instead be thrown at the prey, like a javelin. Having a throwable blade at hand, another person might invent how to augment its effective range using a throwing-stick or atlatl instead of casting it by hand like a javelin.

To make a lethal hunting spear requires a blade, though a simple stick carved to a point might serve at a pinch. The invention of the blade-knapping technique enables the invention of the bladed spear, and the invention of the spear enables the invention of the throwing spear. Without the invention of language, little of that ongoing building of invention on invention would be easy. The technique of making blades that could be tied to sticks, and the following idea that they could be thrown lethally might be invented and forgotten time after time. With language could come teaching, so that the art might pass not just from one person to one other, but from one to many with much greater ease. Inventive refinements do not need language, but to be able to pass the invention on to many others rather than one or two greatly enhances the likelihood that it will survive beyond the lifetime of the inventor, and that someone will think of the next refinement.

If the great invention of language is a catalyst for further invention, so also are other inventions, as we discussed in connection with homeostatic loops and networks in Chapter 12. The blade tied to a stick can be used for purposes other than throwing at prey. If one shape of blade tied to a stick can be used for that purpose, another can be used to shape wood into useful configurations. But the possibility of making an axe or an adze by tying a sharp-edged stone to a stick might never have been invented without the prior invention of the spear[26].

New inventions usually consist of combining older inventions in new ways. The US Patent Office codes patents according to the technologies (the “atoms” of inventions) that they use. Youn et al. (2014)

26. These examples are, of course, purely hypothetical. The historical sequence of these inventions might well have been very different.

analyzed 200 years of patents and found that about 60% of inventions use new combinations of technologies, whereas 40% are reconfigurations of combinations that had already been used. Even though the rate of introducing new technologies slowed after about 1880, when they considered the set of all possible combinations of pre-existing technologies, they found that the space for finding new combinations has been growing faster than the pace of using new combinations, which means that the possibilities for invention are growing ever greater, at a rate that increases with the number of inventions already patented.

In information-theoretic terms, the Universe macrostate increases proportionately faster than the combined sizes of the macrostates of the inventions. In other words, inventions on average become increasingly refined over time relative to the possibilities that become available.

To see how fast the universe of possibilities increases when a new dimension is added, consider the structural macrostates discussed in Chapter 5. Our 225-bit 15×15 checkerboard universe of dots allowed 1.2×10^{34} ways 25 dots might be arranged. If each dot could be either red or black (a newly invented possibility), the number of possible arrangements is multiplied by about 33 million (2^{25}). Adding new possibilities of blue or green (which builds on the earlier invention of colouring the dot) multiplies the possibilities by about a quadrillion (10^{15} or 2^{50}), making something like 1.3×10^{49} different arrangements of the 25 coloured dots in this small space. It is hard to find a comparison for such a large number, which is perhaps only a million or so times smaller than the mass of the entire visible Universe in kilograms[27]! But the space of black, red, green and blue dots on a 15×15 board is minuscule compared to the possibilities for combining different perceptions we can control by acting on what they represent in our environment.

Invention requires control in imagination. "*I want to be able to control my perception of being on the other side of this brook without getting my feet wet, but I have no atenfel for that. I see a plank lying there that looks long enough. I can imagine putting it across the stream and walking over it*." One would probably not pick up the plank and lay it across the brook just for the pleasure of perceiving the artistic structure "plank across a brook". More commonly, one does it specifically to create a new atenfel. Put more technically, in imagination one is controlling a perception of one's ability to control another perception. As the adage says: "Necessity is the Mother of Invention". An invention that appeared to serve no purpose might well be considered not to be a real invention at all.

Reorganization, in the crude form of "if at first you don't succeed, try something different", is a process of invention at its most primitive. Putting stepping stones in the brook, finding that they soon get washed away and don't stay dry very long, then seeing the plank and laying it across to the other bank, is a lightly less primitive process of invention by incremental improvement. Spending years trying out different enclosures and filament material in order to create an incandescent lamp that lasts for a useful time is a yet more advanced form. Using mathematical tools in conjunction with experiment to create a transistor goes even further, invention piling on invention.

Existing tools, which are the result of earlier cycles of invention, may provide atenfels that might allow the inventor's perception if only they were configured a little differently. No existing artifact or set of artifacts currently permits that new configuration, but if "this" were a little different and "that" were to go "there", the result would provide the desired atenfel.

Tools engender tools, or so an alien observer might think. The alien observer would be suffering from the inverse of the "behavioural illusion", in that it might see the tools as the creative actor rather than recognizing the creation in the inventor's control of perception in imagination. Nevertheless, without the old tools, the new ones do not come into being.

27. An estimate provided by Wolfram Alpha 2011.04.24

Invention, by providing new atenfels, not only increases the number of perceptions one can control, or changes how easily and accurately one can control them, but in doing either of these things it necessarily changes the way people act. That is its benefit, but also its vulnerability. If there is a Giant Virtual Controller controlling a virtual perception of doing things, with the old way as a reference value, then someone using the new way is likely to be corrected. The invention might be suppressed and the inventor chastised. Witch trials of people who understood the medicinal properties of herbs come to mind[28]. A farmer using a no-till method of preserving his topsoil may be scorned by his neighbours who have always used time-honoured tilling methods they learned in childhood (while losing their topsoil to blown-away dust and fluvial erosion). Giant Virtual Controllers are likely to be conservative (though not in the political sense, in which "Conservative" often means supporting radical change, at least in the English-speaking world).

What constitutes the actual invention? An invention is never a tangible object. It could be a description or a process that allows an object to be created that the inventor could proudly display as "my own invention". Whatever the inventor might say, the object is not the invention; if it were, another identical object would not be the invention, whereas one might expect the inventor to be able to say "these are my invention". The invention is the structure of the object, and only the novel aspect of the structure at that, since most parts of the structure had been invented previously. They just had not been put together in the novel structure that allows the invention to do what it does.

III.6.2 Cultural Convergence

As we have argued in many different ways and will again, in individuals who use protocols to control some perceptions reorganization will tend to drift their methods of display toward some common intermediate form. That display will probably use verbal language and body language as the action outputs that disturb the other partner's controlled perception in order to control their own. We can see this convergence by mutual reorganization as being analogous to a form of gravity, each partner's way of displaying particular states having a conceptual "mass" that attract's the other partner's way of displaying states. Of course, what happens is functionally unlike gravity, and is probabilistic rather than deterministic, but since on average, successful reorganization will bring them closer rather than driving them apart, we can make the analogy.

In the opposite case of separation, such as between the different branches of Len and Sophie's family, or in our discussion of Nonconformity, a protocol used with a particular individual for a particular purpose may split into a variety of forms that use different displays. We see this in languages such as Japanese or Korean, in which the modes of address used to older and younger people, or to people of the same or different sex, are quite dissimilar, as illustrated at the end of Section III.3.4. The same occurs in English, though to a lesser extent, in the use of words such as "Darling", "Honey", "Sir", or modes such as "Would you mind very much [doing X]" as opposed to "Please [do X]" or "Go and do X, NOW".

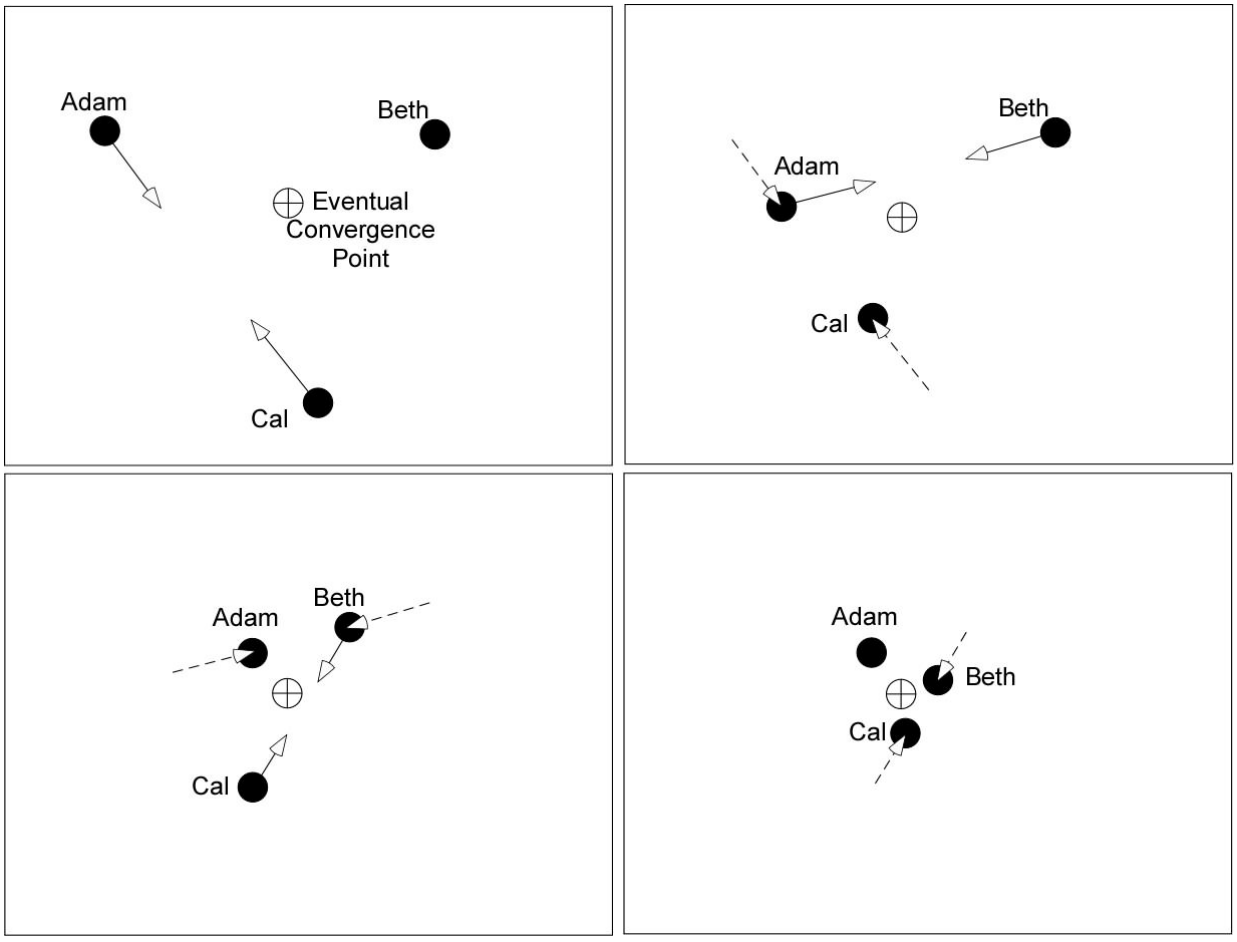
A "public" protocol display in which the parties are playing more generic roles is more interesting, as apart from the Schism we just discussed, it leads to a natural "gravitational" clustering, analogous to the

28. The word "witch" derives from a proto-Indo-European form with the connotation of lively, strong, and aware, through Germanic forms implying wakefulness. The "witch" could see what others could not, and therefore could act in ways others could not — "any sufficiently advanced technology is indistinguishable from magic" (Clarke, 1962/1973)

clustering of matter (both ordinary and dark) in the Universe into stars, galaxies, galaxy clusters, and galaxy superclusters[29]. We now suggest how this might happen.

Figure III.6.1 illustrates a possible welcoming introduction of a newcomer (Cal) into a different culture. In this case, all the actors speak the same variety of English, as opposed to Marcel's problem when trying to make his way among the J's (Section III.3.5). The newcomer's problem is not linguistic but cultural. Eventually Cal will converge to the protocol structure in the culture inhabited by Adam and Beth, just as Marcel would learn the language of the J's.

Figure III.6.2 illustrates schematically this convergence. The three individuals we call Adam, Beth, and Cal from the cartoon of Figure III.5.4 sometimes use a particular kind of greeting or welcoming protocol. They are all controlling for having the protocol go smoothly, but all start with different reference values for its structure, such as the appropriate display language structure for different stages in the protocol. Let us see how Adam, Beth and Cal arrived at their particular protocol form using the gravitational analogy. We assume that Cal has no interaction with others who collectively use protocols familiar to Adam and Beth. For the purposes of the illustration, we assume all three of them have prior references for the perceptions controlled when "greeting" a stranger into their social group, but are willing to compromise and devise a new protocol peculiar to the three of them.



29. While we are using the cosmic metaphor, we might as well think of the separating effect enhanced by lateral inhibition among these clusters at different levels as analogous to "dark energy".

Figure III.6.2 Stochastic Convergence of protocol properties. Adam, Beth, and Cal initially have different reference values for how some property of the protocol should be. Protocols work better if each reorganizes so that their reference values agree better. They interact pairwise from time to time, and gradually, with each interaction, all their reference values converge to a common understanding of how this protocol should proceed. The effect is similar to a gravitational attraction between the individual reference values. The lengths of the arrows that show the effect of reorganization after an interaction are greatly exaggerated, and show average effects, since any single reorganization event might move the values in any direction.

The axes of Figure III.6.2 represent two properties among the many needed to describe the protocol. Each time a pair interacts, the two parties on average move their reference profile values a little closer, for use when they next perform this kind of protocol. Panel (a) shows an early state, just after Adam and Cal have first interacted and reorganized in the direction shown by the arrows (the lengths of the arrows is greatly exaggerated. Because any individual reorganization event could be in any direction, their direction is a representative average, rather than a deterministic pointer).

Adam wants to introduce Cal to his colleague Beth, but Cal interacts wrongly with Beth (Panel (b)). Cal's and Beth's perceptual control hierarchies reorganize to improve relationships, resulting in Panel (c) (after the interaction shown in the cartoon), Panel (d) illustrates the further convergence within the pairs as time goes on. Eventually, they all agree as to how this protocol should proceed, with their reference values at the location marked with a cross in a circle.

The impression is rather as though the reorganizations induced by the stochastic interactions had an effect analogous to gravity. One major difference to this pseudo-gravity is that the "gravitational" proximity of two people with respect to a particular kind of interaction is determined by how often they use that protocol together, not by how close they are in their initial reference values. Figure III.6.3 Illustrates the issue. In this Figure, four people use the same type of protocol with each other, but Adam and Don interact much more often than either does with Cal or Beth, who interact frequently with each other. Don's initial reference values for the way the interaction should be performed are closer to Beth's and even to Cal's than to Adam's, but his reorganization depends on his much more frequent interactions with Adam.

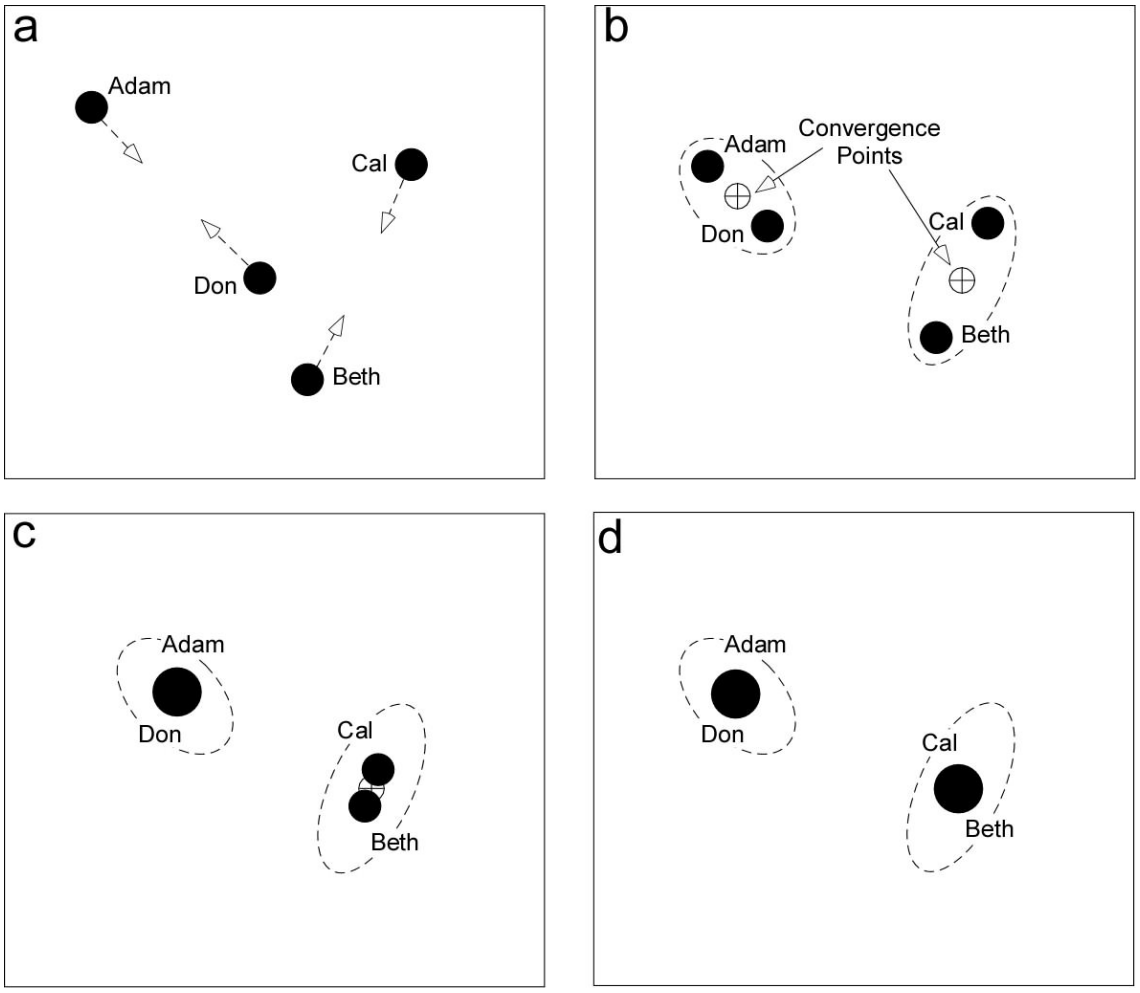


Figure III.6.3 Quasi-gravitational convergence of reference values to different centres, depending on the relative frequencies of interactions between different pairs of partners. Adam and Don interact frequently, but neither interacts much, if at all, with Cal or Beth, who interact frequently with each other. As before, the arrow directions should be taken as averages over many interactions, and the lengths are exaggerated.

Interactions, like a pebble thrown at a Puck in Section III.1.2, occur once and are done, even when the same people interact frequently. In Chapter II.9, 20, and 25 we suggested how people reorganize (such as Cora and her baby Ivan, or Len and Sophie, or Marcel among the J's) to make protocols work well. Now we are arguing that in the network of interactions among more people stochastic collective control will tend to converge their reference values, though possibly not in the same place for everybody, if their interactions frequencies vary widely.

Why do we talk only of individuals in this process, rather than of roles? It is because it is individuals that reorganize. Roles are an emergent collective formed of many individuals who control similar perceptions in similar ways, when using protocols in which the partners are themselves exemplars of complementary roles. We continue with individuals.

The convergence point for any pair that do converge may zig and zag randomly as the individual reorganization events chance to cause changes, but the collectively controlled convergence point will be somewhere near the mid-point between two individuals, or very near the already collectively controlled value of a Giant Virtual Controller, consisting of people whose interactions have already converged their reference values. In Figure III.6.4, Adam and Don form one such GVC while Cal and Beth form another with a different way of performing the same kind of interaction. The Adam-Don and Cal-Beth pairs become distinct Giant Virtual Controllers for the specific protocol display.

In Figure III.6.4 we assume that they do not conflict, because they seldom interact, but the increased gain associated with collective control means that the collectively controlled properties of the display when they interact with someone else will tend toward their joint values more strongly than to those of the other individual. An individual who interacts equally with both GVCs will be drawn more to the closer of the Cal-Beth and the Adam-Don display language, but could be in a "partially conflicted" state if she interacts equally often with either pair.

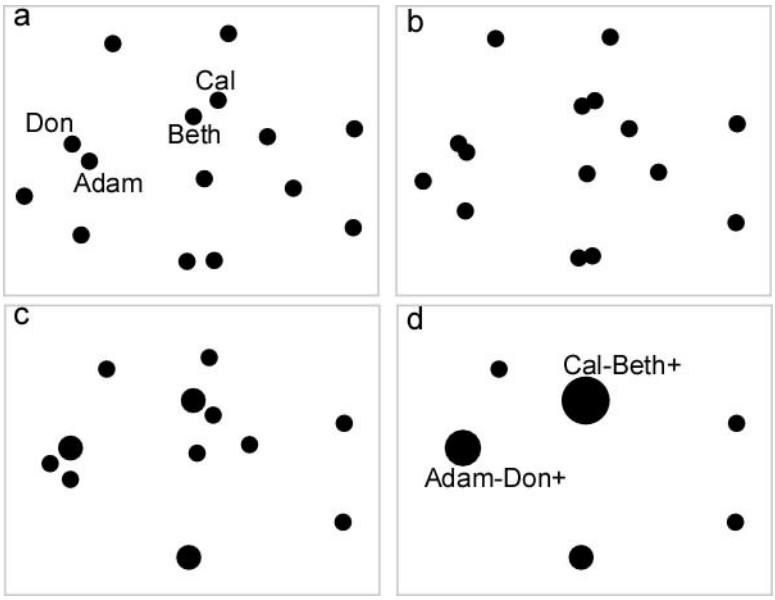


Figure III.6.4 Suggesting the evolution of a particular display for a particular "public" protocol by reorganization in individuals. The axes do double duty, the distance between dots representing both the inverse frequency of interaction between two people and the similarity of their use of a particular display for a particular protocol. The size of the dot represents the number of people using the same display for the same purpose. In (a) everyone displays differently, but reorganization tends to converge displays used by people who interact frequently. (b, c, d) show successive stages of convergence into a few generally agreed forms, plus some idiosyncratic "left-overs".

The same argument can be applied to every display in every protocol. Those who use the particular protocol more often with each other will tend to converge their display language for that protocol more strongly than will those who interact seldom. Groups who use a particular protocol more often will converge more readily than those for whom the protocol is seldom useful in controlling a perception. And since the same display language is used in different protocols, the convergence is at least in part a convergence of individuals rather than simply of protocols or of display language separately.

Since different kinds of protocol are used for different purposes, we see groups that have "in-group" cultural practices and languages, such as researchers in arcane branches of science, people of different religious faiths, sports teams, professionals such as lawyers, artists, realtors, and so forth, all within larger structures that develop for protocols that are more widely used, such as "North Atlantic Culture", and the like. However, the variation of basic language (English, French and Spanish) across very similar "North American Cultures" illustrates that there can be convergence at one level, with distinctness at another. In Figure III.6.4, the Adam-Don group may need to use protocols that converged with those used by the Cal-Beth group while using display languages that never converged.

III.6.3 Language: Broadcast versus face-to-face

Language is used in ways that (apart from "talking to oneself") vary between two extremes that we might call "face-to-face" and "broadcast". Up to now we have been considering direct interaction between the parties in a protocol, in which feedback is immediate or nearly so. The extreme opposite way of using language is in a broadcast to an unknown number of individuals who cannot provide immediate feedback.

Broadcast language occurs in situations such as giving a lecture, creating a podcast, or writing a book. In these cases, if there is any feedback, it happens on a much longer time-scale and cannot influence what the speaker or writer produces[30]. The most extreme case of this may be the gold discs included with the Voyager spacecraft, which carry messages to some alien species that might find them many millions of years hence, along with what is hoped to be a universal means to decode them.

Between the extremes of face to face conversation and broadcasting, there are such interactions as "texting" or speaking to groups of three or four people along the lines of "Should we do this" "Yes, let's" "OK, then. Let's go". We considered the dynamical implications of such timing constraints in fi.4. Now we look again at the implications of this continuum, particularly at the broadcast extreme that we have so far neglected.

Language was used for millennia before it could be written. Only those within earshot of a speaker knew what was said, and a speaker usually could see and hear the audience members. It was "on-line" and feedback was immediate. In contrast, a writer usually writes for many potential readers, most of them unknown, and some of them perhaps not yet born. Feedback, if it occurs at all, is long-delayed. The same is true for a designer of highway signs or a TV lecturer. For them, the lack of feedback to correct misunderstandings means that error reduction must occur through redundancy, including the situational context in which the message is supposed to be received.

As is true of any action according to PCT, the writer still writes in order to change some perception she is controlling. In the case of a writer the controlled perception might well be an imagined state of the future reader. Such a perception cannot be controlled in the way one protocol partner controls a perception of the other. The writer instead must control in imagination using a World Model that includes the perceptual abilities, belief structures, and control organizations of the imagined people for whom the material is written. Those properties define the culture of the intended readership.

When a writer writes for a specific reader in a situational context imagined known to both of them, she writes only as much as is necessary to disturb the reader's controlled perceptions in the desired way. A scribbled note on the kitchen table saying only "236.50 John" might be enough to have you pay your

30. Although the audience at a live lecture can provide limited immediate feedback by collective control if many of them show, for example, approval or disapproval, understanding or puzzlement.

plumber friend who was at your house while you were out. You understood it exactly as though John had written "*I was here for quite a while and installed some new stuff to replace the things that were failing. It should all work now. The total parts and labour comes to $236.50. (signed) John Pedrillo*".

When writing for a wider audience, the author cannot make such specific assumptions about the state of the reader beyond assuming some commonality of culture. Commonality of culture means the existence of certain sets of perceptual functions that allow the readers to perceive something about whatever the author is controlling for them to perceive. Sometimes, very little commonality can be assumed, but at other times the assumption can be very tight, constraining greatly the information that must be explicitly written.

Writers are often asked "Who are you writing for?". The intended readership provides this constraint. This book, for example, is written for people who are willing to be persuaded that Perceptual Control Theory is likely to be widely useful for matters they care about, and who want to understand it without recourse to mathematical argument.

The highway sign designer presumably assumes that an unknown oncoming driver will want information about things to do with driving conditions and directions, and will put on the sign only so much as a moving driver needs to know. The driver may be assumed to be travelling near the average speed for the highway and have vision good enough to have a driver's licence. These parameters tell the sign designer how much text or how small a symbol the driver could take in while the sign will be in view. Not knowing the driver, the designer will not display things anyone arriving at that point in the road is likely to know already, because including that material would take away from the driver the time that could be devoted to understanding the new material. As most drivers will have observed, not all designers of highway signs limit themselves in this idealized manner.

Sign designers sometimes go to the other extreme, omitting the necessary information while including what the driver probably knows already. Many years ago I was driving in the Lake District of England, where the roads are twisty and small villages and towns are many. I had a map but was not sure where I was. In the distance was a signpost that I hoped would tell me, but when I came close enough to read it, what I read was a pointer to "THE TOWN". Such a sign could be useful if the problem was to know which road led to the town as opposed to various local farms, but I wonder who among the locals, who presumably knew which town it was, would not know which road led to it?

Lecturers and writers tend to speak or write in full sentences and present all the words explicitly, something people in face-to-face conversation seldom do. In ordinary conversational interaction, many — or even on occasion all — of the words in a "sentence" may be unspoken, replaced perhaps by the lift of an eyebrow. For example, the other day my doctor suggested an appointment at an earlier time of day than I like. Before I said any words to tell him it was a bit early for me, he said "I know that look. How about [a later time]".

There is a story, probably fictional[31], that when Victor Hugo wanted to know how the sales of the newly published *Les Miserables* were going, he wrote the following letter to his publisher: "?". The publisher replied: "!". Fictional or not, that the story has seemed plausible illustrates the point. Hugo could not sensibly have written "?" as the entire text of something intended for wide distribution, or even, perhaps, to anybody but his publisher. Indeed, the story would make no sense if Hugo had written to the same publisher at a time when he had no newly published work about which he might have been concerned. Only at a time when Hugo perceived that the publisher would perceive him to be wanting to know about sales would the message pair make sense.

31. See http://quoteinvestigator.com/2014/06/14/exclamation/ for an analysis.

The question mark indicated to the publisher that Hugo was initiating a Question-Answer protocol, and in that situation it was sufficient for the publisher to perceive the Question. The feedback loop might take days to complete, but from Hugo's viewpoint, he expected that it would complete. He had allowed the publisher to perceive that he was controlling a perception of knowing how his book was selling. He anticipated that the publisher would be controlling a perception of Hugo's happiness with him, a perception that would be disturbed by the sight of the questioning letter. Both Hugo's and the publisher's controlled perceptions would approach their reference values if the publisher sent a suitable response, which the publisher chose to do in the form of an exclamation mark, which Hugo would read as though it had been the entire sentence "Your book is selling even better than we hoped".

Hugo's brevity would not work when language is used to harangue a crowd or to write a work such as this, intended for readers with unknown prior understanding of the topic. What is such a reader controlling, and how does the use of language as the action output influence the controlled perception through a feedback loop? The writer cannot tell, so inverts the question and writes for a reader who is controlling some particular perception the writer wants to disturb. The reader is selected by the perception, rather than the reverse as is the case in a face-to-face interaction.

What we can say for sure is that feedback through the external environment relating to the influence and even the intelligibility of the content of broadcast language is much delayed, except possibly in the case of the orator in front of a live audience. While talking, the orator may be able perceive the approval or disapproval of the crowd as a whole, or of a few individuals in the audience. Even so, the orator has little or no chance to use supporting GPG levels to correct misunderstandings that may occur in individual members of the crowd. Feedback cannot be very effective, so the orator must rely on syntax (redundancy) to improve the chances that audience members understand what was intended.

A publication for a general audience requires trust. The writer cannot get timely feedback to determine whether the written material has the desired effect on the reader. Has the reader done what the writing exhorts? Does the reader now understand what the writer intends should be understood? The writer cannot know until it is much too late to amend the written material. It is out in public circulation, and there it will probably remain, perhaps followed by correction, but still available in uncorrected form. To get around this problem, the writer takes advantage of syntax at many levels of discourse, from letter sequence to argument structure.

"Syntax", "redundancy", "the creation of small macrostates within a larger universe of possibility", "sequential coherence", and so on, all label the same concept. They are words used by people playing different roles and therefore using the concept in different contexts. Someone who calls the concept "syntax" is playing the role of "linguist", whereas someone who calls it "redundancy" is playing the role of "information theorist". These differences should not cause misunderstanding, provided it is clear that they all mean the same thing.

Even though written material for a general readership cannot be part of a true protocol, nevertheless the writer is like the initiator of a protocol in that both the writer and the protocol initiator act to bring some perception in the partner (reader or protocol partner) to some desired state, the writer controlling in imagination, the reader controlling in imagination through a feedback loop that encompasses the writer.

Like the user of a protocol, the writer operates within a community. Writing in a monthly newsletter for a sporting club, a writer might say something like "The Sparks B seven took the Blazers 18-3 on Sunday 18th", a string that would make no sense either to a general readership or in an academic paper the same writer might write for his parasitologist colleagues. The "language" used in writing borrows from the language used in protocol interactions with people playing the same role as the intended readers, though it is not the same.

III.6.4 Broadcast language as “Official”

We return to the concept of the “Giant Virtual Controller” as “Authority”, and extend the concept to a more formal kind of “Authority”.

When the writing or speech is targeted at an unknown recipient, some common denominator must be assumed. That common denominator is usually “the language” of the target audience, for example “English”, “Russian”, “Farsi”, “Lao”, or “Japanese”, or a sublanguage, such as that used by physiotherapists, Middle-Eastern archaeologists, or Bollywood movie fans.

If the writing is to have the desired effect on the reader, the writer and reader must have some common reference perceptions of how the words, phrases, and other structures might be used in protocols. This common ground is called “Linguistic Information” in Section 10.10 (Figure 10.15) and by Nevin in his chapter for LCS IV. Over time, the common ground has been developed through collective control, and the writer assumes that the reader has reorganized to conform, at least to some degree, with the reference values asserted by the Authority — in other words, that the reader has an adequate understanding of the language.

If I were to use in running text a word that I now invent for this occasion, “*flamingotten*”, it would not mean much to you. It isn’t part of any language or sublanguage you know, though you probably have used “flaming” and, depending on your dialect of English, you might have used “gotten”. But you don’t know whether I intended you to perceive something obtained by means of fire. Maybe you also have used “flamingo” and perceive “-tten” as some kind of modifier you have not previously encountered, referring perhaps to a property of a flamingo distinct from other birds, or something derived from some property of a flamingo. Perhaps I am talking about a fabric that has the coloration of a flamingo.

Or maybe I mean something entirely different. You don’t know, so if I want to use such a word, I have to use it in a context that allows you to perceive how it fits into the entire situation I am describing. In the terms of Section 10.10, I would use syntactic and semantic coherence constraints to help you to add “flamingotten” to your linguistic information. In his chapter in LCS IV, Nevin argues that such constraints are what we use to place every word in a small equivalence class, perhaps even in a class by itself. Such equivalence classes can be seen as conceptual macrostates.

Since the first time you encountered “flamingotten” was only a few lines ago, in a context in which the necessity of common understanding was the primary focus, you probably have correctly perceived the word to be one I intended as an example of the ineffectual use of fancy words that the reader is unlikely to know. But suppose that instead I had introduced it in the following context (which consists of some probably false statements about a few European languages):

> *The Low countries encompass several linguistic regions, regions in which the language spoken is quite different from that spoken in other regions. Some of these languages have names, such as French, Flemish, Fries, Dutch, and German. But there are borrowings between the languages, so that Frankish words such as “champignon” appear in Dutch and German, while flamingotten words are seen in German and Dutch, but not in French or Fries.*

In that context, you see that “flamingotten” has no connection with fire or flamingos, and if you were to see it again when you read something else, you would understand that it is an adjective and, by elimination you might guess that it probably refers to a word derived from Flemish used in another language.

If I had not just invented "flamingotten" and told you so, you might have gone to a dictionary to look it up. Why would you do that? It's an action, and according to PCT, all actions are to reduce error in controlled perceptions. If I were to ask you why you went to the dictionary, you would probably answer something along the lines of "I wanted to know what it meant." You probably would not say "I wanted to know what you intended me to understand."

"What it meant" is an absolute statement. The dictionary represents Authority, and if I had used "flamingotten" with the intention that you should understand something other than what the dictionary says, you might justifiably tell me I misused it. The dictionary is supposed to supplement the "information known to the listener/reader" part of 12.10 in cases where the talker or writer wrongly assumed the listener/reader to have known a word. My "misuse" of the word, and your telling me of my misuse would be an instance of the general collective control of the meanings of words.

How does the dictionary come to represent Authority, when "Authority" is a Giant Virtual Controller with idealized reference values that cannot be localized in any one brain? This question comes down to the perennial one of whether a dictionary (or a grammar book) is a prescriptive or a descriptive device. The answer is classic PCT: it is both, in a feedback loop.

Without the dictionary, the Giant Virtual Controller simply corrects a misuse when it causes the intended reader/listener to misunderstand the writer/talker. Using the dictionary, the writer can use a word in the way prescribed by the Authority, and can anticipate that the reader/listener who does not know the word will look it up to see how the Authority describes it. Moreover, if someone corrects a use of "flamingotten", claiming it to be a misuse, the speaker could tell the complainant to "look it up", using the Giant Virtual Controller to alter the complainant's perception of the word's "proper" usage.

The dictionary itself is a CCEV, or rather, a myriad of CCEVs, since as language drifts in general use, the reference values it prescribes for changing words will become less and less descriptive of the way they are actually used. But it also serves to reduce the amount of that drift, if people use its prescriptive function to determine how they actually use words.

In our discussions of Len and Sophie's family, we suggested how both the sounds of language and the meanings of sound sequences might drift away from the original forms used by Len and Rob in their earliest protocols. If each new family member had been introduced to protocols by exposure to Rob, this drift, if it happened at all, would have been much attenuated. New protocols for novel situations might have been developed for use within the family, but those used with Rob by everybody would remain fairly stable, with variations among individuals only within the range that allowed them successful interaction with Rob.

In this scenario, Rob is an "Authority", stabilizing the execution of the protocols with which it was programmed, while allowing for the development of new ones among people not interested in using them in interactions with Rob. In the real world, a dictionary or an institution such as the Academie Française has much the same effect. If someone wants to use a dictionary to find the meaning of a word, that meaning, for that person, moves toward whatever the dictionary describes. But most people, most of the time, do not refer to the dictionary, or, for that matter, to the Academie Française.

Of course, if the person uses an unfamiliar word in an unhelpful context during a face-to-face protocol interaction with someone who has not consulted the dictionary, the protocol is likely to fail. But if the person includes the word in a broadcast use of language that does not imply the existence of an immediate feedback loop, the listener/reader has time to look up words in the dictionary. This ability allows a writer to use words not ordinarily heard in conversation, words that may have a precise dictionary definition to which both reader and writer can refer.

III.6.5 Broadcast language: drifts and definitions

The widest reader role for a writer to consider is the general public, the entire population of, say, a related group of countries. To write for such a readership implies that very little can be assumed about what the individual reader already knows. The consequence of this problem is that to say anything significant requires the writer to include a lot of preliminary material to explain the intent of the significant item. In fiction, the writer must allow the reader to perceive the fictional world. In non-fiction, the writer must be sure that the reader has sufficient basic knowledge to be able to understand whatever novel ideas the writer wants to get across.

Laws are intended to apply to everyone in a country and to convey the same perception of the intent of the writers of the laws, no matter who the reader might be. In order that everyone should understand the intent of a law, it needs definitions that specify anything complex in terms everyone should be expected to understand. However, there are so many such terms that to write them into every law would make it difficult even for an expert to discover whatever is novel about this particular law. There might just be one key element embedded in one sentence among several hundred pages that consist essentially of definitions, most of which would already be known to an expert in law.

The solution for this dilemma is to direct the written form of a law not toward the general public, but toward people in a special role, a role consisting of people who understand the definitions and many of the relational implications of the language used: lawyers. Lawyers can then interpret the law for the general public as necessary.

The word “definitions” featured prominently in the previous two paragraphs, but where does the concept of “definition” fit within PCT? A definition is a description of what features should be present if the defined word is to be used properly. In other words, it is a partial description of a perceptual function, but it is itself just a string of words, not a perceptual function. The string of words is input to whatever perceptual functions interpret language into other forms such as images, and in a definition both the word string and the resulting images co-occur with the word being defined, potentially creating the kind of associative link discussed in Section 9.6. As suggested there, it may be more important that the definition specifies what the word *does not* mean, a high-level version of lateral inhibition that bounds a tolerance zone for the “Giant Virtual Controller”.

The definitions in a dictionary provide context, as does the use of a word like “flamingotten” in an appropriate situational context. The context, however, is of a different type. Whereas “*flamingotten words are seen in German*” used in a discourse illustrates how the word might be used, “*flamingotten: adj; of words borrowed from Flemish for use in another language*” describes the Authority’s reference for how the word should be used.

When we think of PCT reorganization, the two concepts of “describe” and “illustrate” are almost diametrically opposed. The dictionary definition provides a logical description of where the word is used according to the Authority, whereas an illustration provides a perception of when it “sounds right”, without putting any rigid boundaries on what “sounds right” means. A definition provides a conscious perception, whereas use in casual conversation leads to the creation of a perception controllable non-consciously. Definitions consciously divide, whereas illustrations create implicit and not necessarily conscious relationships. The two defined and evolved perceptions of “flamingotten” are different, but both are possible candidates for association between the word and its ordinary meanings at that level.

The reader who first came across “flamingotten” while reading, in a context such as “*flamingotten words are seen in German*” might later say in conversation something like “Champignon is a flamingotten word in German”, thinking it meant any borrowed word, rather than a word borrowed specifically from Flemish. If the conversational partner was more familiar with the word, or had looked it

up in the dictionary before responding, the response might be “No, ‘champignon’ comes from French”, which might bewilder the original speaker until the problem was explained or reference made to the dictionary.

If, however, the partner did not know the dictionary definition, but assumed that the first speaker used it correctly, for both of them the word might develop an range of meaning expanded beyond the dictionary definition. They would have reorganized their associative connections so that their mutual understanding was that “flamingotten” meant “borrowed from another language”. And for them, if not to others who had looked the word up in a dictionary, it would. Few people look up unfamiliar words heard in conversation, or even words read in a book, unless the unknown meaning is essential to understanding the higher-level intent of what is heard or read, and then only if the higher-level intent is important to their control of some perception.

At a low level, typographical errors are often hard to spot because they are perceptually corrected using redundancy in the text (Figure III.6.4), and in any case are not likely to make any difference to the higher-level meaning. Likewise, at higher levels, uninterpreted elements may be passed by without a hitch. But even if they are noticed, they were probably perceived near words in the same semantic domain, and perhaps also in a relevant pragmatic context.

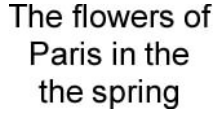


Figure III.6.4 A well known example of some text in which a typographical error is often missed the first time someone sees it.

If the unfamiliar word is again perceived in the context of words in a similar domain, the reader/ listener might already acquire by association a sense of the meaning. But that meaning would not necessarily have be quite the same as was intended by the writer/speaker. As with the invented “flamingotten”, words and protocols can drift in meaning, and that drift might be different for different people.

Not only may words drift in meaning, but also they can drift in sound. If, unlikely as it may seem, “flamingotten” were to be used a lot in casual speech, it would be quite likely that some part of it would be elided, so that the word might eventually come to sound like “flatten” or “flammen”, much as in the USA, the word “President” often is spoken as though it had only one syllable “Pre’n”, or in England, Worcester is pronounced “Wooster” and Cholmondley as “Chumley”. Such elision-based drifts as well as other kinds of drifts could lead a word spelled “flamingotten” to be pronounced much the same as some other word “flatten” that has a quite different meaning. Most languages have many such homophone pairs, not always caused by elision. Children often like to play with them, as in the almost universal “I scream for ice cream” among English speaking children. As we saw in the story of Len and Sophie, the discriminability problems are usually resolved by differences in higher-level trajectories. Only one of the meanings of the words or word strings make sense in context.

If homophones were common among protocols used in any particular cultural group, it is unlikely that many of them would remain in use for very long, since a misunderstood protocol implies a failure to control the perception for which the protocol is being used. Control failure leads to an increased reorganization rate. In general, confusion in the use of protocols must, according to a fundamental principle of PCT, lead to reorganization that reduces the confusion, perhaps by biasing the situational contexts in which the confused protocols are used, so that the situation comes to determine the intent of the homophone, or perhaps by shifting the pronunciation of one or both homophones so that the protocols

cease to be confused. However it is done, if two protocols are easily confused, their users are likely to reorganize in some way.

Language drift seems not to be uniform over time; Atkinson et al. (2008) provide evidence that when a source language splits into separate daughter languages, the drifts that define the split are accelerated. That acceleration may be an example of the lateral inhibition discussed in Chapter 9, and related to the mechanism proposed for phonetic symbolism proposed by Taylor and Taylor (1962) and described in Section II.12.9. If there is a pair of words with similar meanings in the source language, some cultural subgroups may use one more than the other, while the reverse might be true for members of other subgroups. Perhaps the groups are separated geographically, and over time the patterns of preferential uses of one word over the other in many pairs, and the concomitant changes in protocols using those words, are numerous and coherent enough to allow the manners of the two groups being called separate cultures with different dialects or even different languages.

Regional dialects identify their speakers as belonging to a particular culture with protocol forms that may differ from one region to the next, with the result that controlling a perception of self as belonging or being perceived to belong to group A requires the use of the preferred "A" form as opposed to the "B" form even though both might still be perceived as meaningful. Collective control by members of group A might be in the form of accusations that a person who used the "B" form was self-identifying as "not one of us".

There are therefore three mechanisms that might account for the punctate evolution of the split languages. All of them seem to be implicated in the North-South splitting of the Korean language that is currently ongoing (Kim Hyung-Jin, 2015), but the last — collective control of perceived group membership— seems to be most important, at least in North Korea, where the authorities stress the "Korean purity" of the language as a contrast with the infiltration of English-like forms in the Western commercial culture of modern South Korea.

III.6.6 Cultural Drift

The cartoon of Figure III.6.1 (above) showed collective control in action. A new graduate student who we called Cal is introduced to an older student we call Beth by another graduate student we call Adam. But Cal commits an error by asking Beth about the progress of her research, a taboo question. Adam, who is executing a triadic "introduction" protocol perceives that Cal is executing the supporting dyadic "greeting" protocol incorrectly, and acts so as to create error in the "greeting protocol form" perception Cal is controlling. At the same time, Beth, the potential continuer of the greeting protocol, shows displeasure rather than the pleasure Cal expected.

All of them experience error in their various controlled perceptions, but as a newcomer to this culture, it is Cal who is most likely to reorganize in such a way that he executes a greeting protocol differently the next time he is introduced to a new colleague. The other two are less likely to reorganize to change, because they have long since reorganized to control successfully their perceptions of the form of greeting protocols collectively controlled by that community.

Figure III.6.5 shows a possible set of profiles of the reference values for the different features of a "greeting" protocol held by Cal and by the old-timers, among whom are Adam and Beth. The solid line represents in a "greeting" protocol the reference values for the features that have been collectively reorganized in Adam and Beth, the two old-timers, while the dashed line represents Cal's reference value profile. The two profiles agree within tolerance ranges except for one value, for which Cal's reference value differs markedly from the CCEV reference value established for the other two. This deviation is, in

the cartoon, sufficient to bring the old timers' perception of Cal's "greeting" protocol outside their collectively controlled tolerance zone.

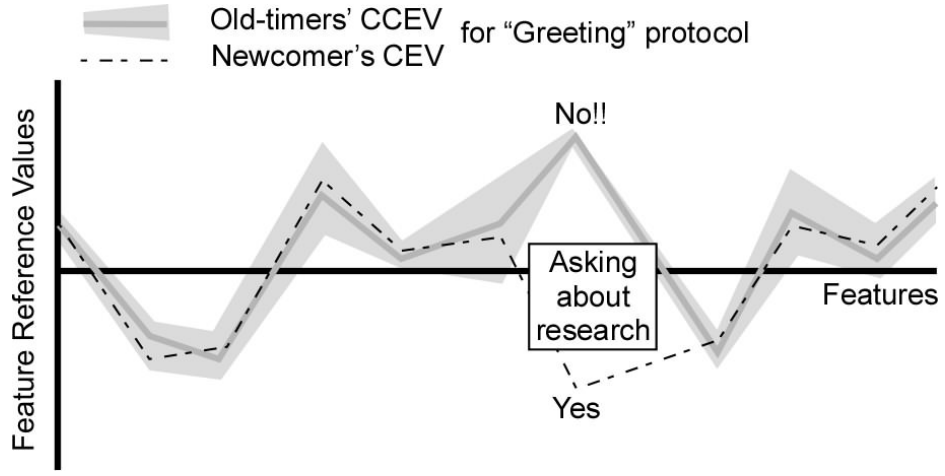


Figure III.6.5 A culturally developed CCEV may not be the same as one developed for the "same" interaction in a different culture. The newcomer's reference profile for the controlled perception of a "greeting" protocol differs in one important respect from the profile developed in the culture he is joining. The width of the grey area suggests the collectively controlled tolerance zone about their reference values for the different feature perceptions in the new culture.

Some people interact together more often than they do with other people, as suggested by, for example, Figure III.6.3. If Cal later collaborates with Beth as a research partner, they will interact using a variety of protocols together more often than either will with Adam, who studies a different subject altogether, and much more often than they will with Olga, a cashier in a supermarket on the other side of town, or with Nhidini, who lives in a village on another continent.

When Cal and Beth have worked together for a while, they will probably have reorganized to have common protocols for matters concerned with their work, and perhaps for other matters, too (Figure III.6.2). When either of them interacts with someone else using a protocol to control a similar perception, there are two possibilities. They may perceive their particular protocols to be "private", and refrain from using the same displays when interacting with others for the same purposes, while they may perceive other protocols to be "public" and usable with other partners. Their collective control of private protocol forms will have different reference values from the reference values they use for the same protocols when interacting with the wider graduate student community, and those again may differ from the patterns of the same protocols used with members of the general public. In this way hierarchically modular structures of communities tend to develop.

Cal presumably will reorganize to change his way of greeting another student to whom Adam (or someone else) may later introduce him. He may be corrected again, by having one of his controlled perceptions disturbed (as by Adam's slap), and by failure to perceive pleasure in the individual to whom he is next introduced. Cal's reorganization continues through a stochastic collective control process (Chapter xII.13) until he performs the "being introduced" protocol properly within the tolerance bounds of the older students being introduced and doing the introducing.

However, because introductions such as that of Figure III.6.1 are sporadic, there is no guarantee that Cal's reorganization will bring his use of the protocol within the individual tolerance zones of *all* the

other old-timers. He will not have tried greeting all of them, and some he has not greeted might have individual tolerance zones that would not include the protocol profile to which Cal has reorganized, apparently satisfactorily. Cal's profile is not what it was in Figure III.6.5, but it may still be near the edge of the collectively controlled tolerance zone, and his personal tolerance zone may extend outside it.

Suppose that next year Cal, by now an accepted member of the graduate student group, wants to introduce a new student called Derek to Beth. Cal now takes on the role that Adam had when Cal was being introduced. In his various experiences of being introduced when he was new, Cal had reorganized and had been able to avoid several taboo topics in his later introductions. But Cal's reorganization would almost certainly not have left his reference profile exactly the same as either Adam's or Beth's. Furthermore, because his tolerance zone would be different to theirs, when Derek makes a mistake that Adam would have corrected, Cal might find that mistake to be within his tolerance zone and not correct it.

As we saw when we were developing the concept of the protocol (Chapter xII.12), the core requirement is that each party should be able to perceive the relevant perceptual and reference states of the protocol partner. Cooperative partners create displays that make this intrinsically impossible task easier to perform well enough to allow the protocol to achieve the objective of the initiator. Deceitful partners use their displays to mislead the other into misperceiving their reference values. The victim — initiator or continuer — may perceive the protocol to have worked properly, but the resulting state of the world is not what the initiator perceives it to be.

Beth, as the one to whom Derek was being introduced, would probably have a wider tolerance zone than she would if she were doing the introducing, and particularly if she liked the look of Derek, she might avoid showing any small displeasure she felt at a mistake that Cal failed to correct. Since Derek's mistake would be uncorrected, he would not need to reorganize, at least on this occasion. If he made the same small mistake on being introduced to other students, they might not correct it either, so when it became Derek's turn to perform introductions the following year, his reference profile might be outside Adam's, but close enough to allow him to perform introductions for the next student generation in a way that the others would accept as being tolerable, if a little odd.

The argument so far would lead one to assume that if there are any interactions using a particular protocol between two individuals, their reference values for the protocol properties would tend to converge. Eventually all the individuals would converge to the same point, all using the same display language the same way for every protocol. But this does not happen. In Figure III.6.3, Don's reference values move away from Cal's and Beth's toward Adam's because he interacts with Adam but not with Cal and Beth, whose initial reference values were more like his than were Adam's. In Figure III.6.4, various individuals move their reference values closer to either the GVC represented by Adam and Don or the GVC represented by Cal and Beth. But the two GVCs do not converge their reference values. Is this realistic?

One reason for thinking that it is goes back to our discussion in Chapter 9 about Lateral Inhibition. There we started by talking about physical signals and synaptic processes. Now we are talking at a very different level, but similar effects may apply. In particular, one controlled perception that might be involved is of group membership. Jacob may be controlling for seeing himself, and being seen by others, as belonging to the "Sebright Boys" and not to the "X-mall Team".

To bring such perceptions to their reference values, Jacob must use in ways that exaggerate differences between protocols that are similar between the two groups. The same is true for other "Sebrighters" who do not want ever to be mistaken for an "X-maller". Members of the other group equally do not want to have their membership mistaken. In the USA, a Republican is unlikely to want to be seen as acting or speaking like a Democrat, and vice-versa. This form of lateral inhibition tends to cause increasing divergence between the reference values for protocol form perceptions of the two GVCs.

The lateral inhibition effect is likely to be more general than the gangland example implies. The perception of membership in any group may be controlled, which may require that other members perceive that the individual is not a member of some other group. The group may self-segregate, as some religious communities have done over the years, not least the Puritan Pilgrim Fathers who are sometimes credited with starting the United States of America.

Separation, as we have pointed out, can lead to drift, the "Brownian Motion" of stochastic control. Even in the presence of weak "pseudo-gravitational" convergence, Brownian drift might be divergent, and sufficiently so to cause two GVC reference values to diverge even without physical separation between the members of the two groups. GVCs whose members seldom interact with members of other GVCs in the use of a particular protocol will be as likely to drift apart in their reference values for the properties of that protocol as to drift together.

Even without lateral inhibition, the geometric analogy suggests that the average change in the absence of pseudo-gravitational attraction or lateral inhibition bias would be to drift apart at a rate proportional to the square root of time. So we have both direct and indirect reasons for arguing that unless the interaction rates for all individual pairs are similar, nuclear clusters will form GVCs that sometimes will converge and more often will drift apart.

When they drift apart, both sides of the split still need to ensure that the various displays for their separated protocols maintain their mutual discriminability. At a much lower level, for example vocal language, the patterns of vowels in formant feature space are similar for all speakers of the same native dialect, but differ in size and location between individuals, the average size and centre of the pattern for men differing from the average for women, and both from children, while the shapes of all the patterns remain the same, as shown in Nevin's Figure 10 and as suggested here in Figure III.6.6. The actual patterns may differ between languages and even between dialects — for example in some US dialects the vowels in "dog" and "bag" are essentially the same — but the principle holds of spreading the possibilities over the available space.

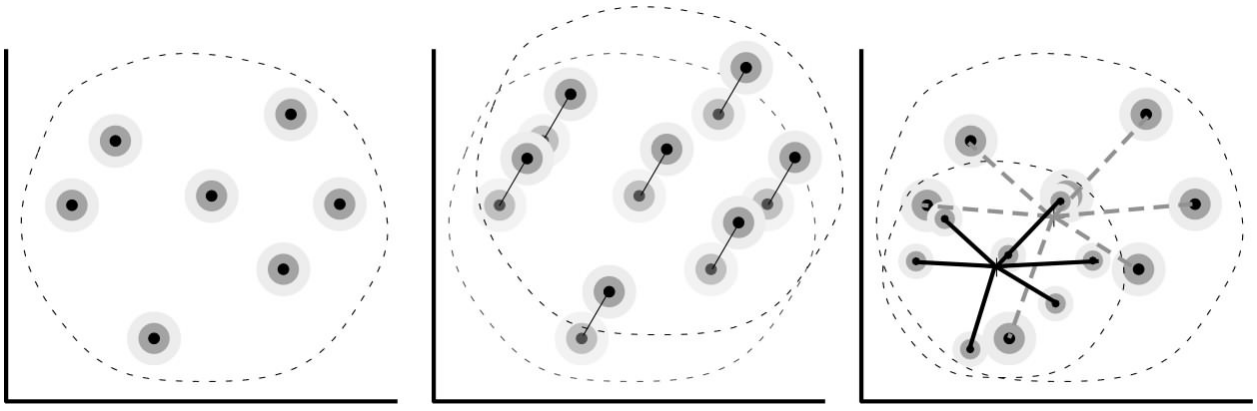


Figure III.6.6 Shifting a "norm" by translating and scaling in the feature space. The grey discs represent arbitrary"syncons" as in Figure II.12.4. The dimensions could be, for example, two formants of the different vowels, or the perceived size and warmth of a words representing concepts. The central point is a "norm" for that person's feature space, against which the individual "syncons" are discriminated. The dashed perimeter represents the limits available to the perceiver for a given producer. The middle panel shows a translational change in the central norm (compare Nevin's figure for the formant values of vowels for men, women, and children in his chapter in LCS IV). The right panel shows the same set of "syncons" for two different producers one of whom has a smaller available range in the feature dimensions.

The same arguments apply many levels of protocol. Discrimination at any of these levels is useful, but discrimination at several makes the listener's task easier. Figure III.6.7 illustrates this. Starting with the raw uncertainty of phonemes (or letters) the various levels of constraint must eventually wind up with little or no remaining uncertainty (within the tolerance levels of the speaker and hearer), but at each of the ten intermediate levels the added information depends on the particular interaction state. Sometimes the pragmatic situation may provide all the required information, sometimes very little. Again, "I scream for ice cream" has very similar sound trajectories each side of the "for", but at any one of the levels from "Syntax Constraint" down to Situational Context (pragmatic) Constraint the overall trajectory may be easily discriminated and the sentence understood.

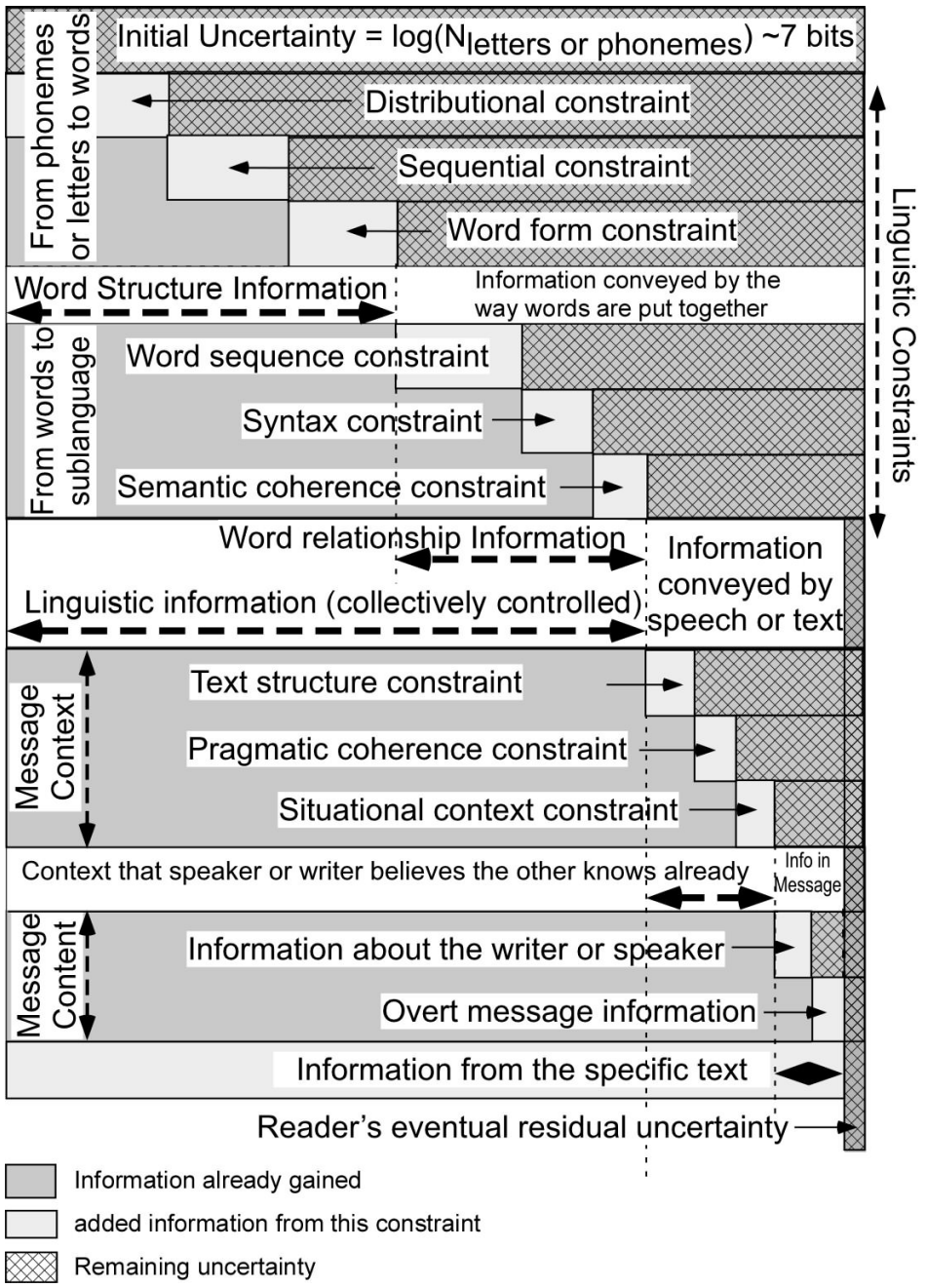


Figure III.6.7 (9.14 reproduced). The trajectories at the different levels for "I scream for ice cream" are ambiguous at the upper levels of the Figure, but may be discriminated, depending on the situational context, at any or all levels below "Word Structure" down to Situational context constraint. In the evolution of a language, the more levels that allow easy discrimination among possibilities, the easier it will be for a listener to interpret the intent of what is said, but even if two trajectories at the upper levels of the Figure (lower levels of the Perceptual Control hierarchy) are identical, they may be easily discriminated using other constraints.

All these commonalities and variations are artifacts that have nothing to do with the truth of perceptions of the inanimate world. Their truth exists only in the partner's perception of the intention of the display. The display means only what the partner makes of it, not what the creator intends the partner to perceive. Humpty Dumpty's claim[32] in "Through the looking Glass" cannot work, as Carroll made clear. The effect is to ensure that if a new concept must be displayed, the choice of display is likely to have two properties. It is likely to contain previously used components combined in a new way, and this new combination will either merge with an existing one or will tend to drive old ones away from its new location in the feature space defined by its components, as suggested in Figure III.6.8.

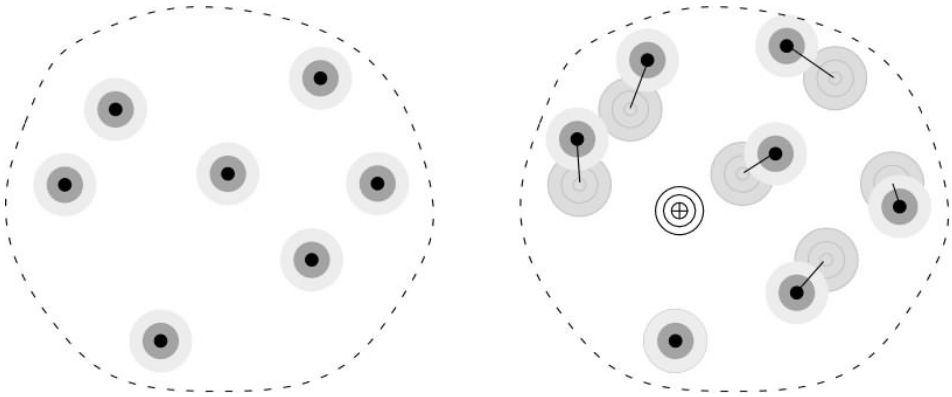


Figure III.6.8 If a new configuration (ringed) is needed within an existing set of mutually discriminable patterns, the old ones may have to move to retain their mutual discriminability. The dotted perimeter represents the extreme limits of available variation in the underlying feature space, which might be, for example, the first two formants of vowels, or the "pleasantness" and "warmth" of the concepts represented. The actual underlying feature space would have more than two dimensions, but the same principle applies.

Sometimes, this move will result in a wholesale shift of the entire display structure, as in the Great Vowel Shift of Germanic languages, or the p-f and similar transitions that relate Romance "pater" to Germanic "father" or "vater", for example. Hogben (1965) provided comprehensive examples from a dozen Indo-European languages, showing how the sounds of one language may be transcribed into the sounds of another, thereby making the sense of words in the foreign language relatively easy to follow even if at first sight they seem quite strange.

The linguistic shifts hinted at here and in the introduction are quite similar in their basic form to the "norm→anchor→deviation" perceptual shifts implicated in figural after-effects, and in identifying individuals, accents, sex and age independently of what is said or represented by bodily gesture. Identifying the individual or some group characteristic of an interlocutor determines how one will execute a particular protocol. Just as it important that the other understand the intent of the sounds and gestures one displays, so it is also important that the protocol be distinguished from other protocols.

Figure III.6.8 can apply just as much to the collectively controlled form of a structure of protocols as it does to the collectively controlled pattern of distinctions among vowel sounds. One person may be perceived as, say, brusque but friendly at heart, while another is perceived to be ingratiating but cold-hearted. What is perceived as friendly in one culture might be seen as offensive in another. Talking over

32. "When I use a word", Humpty said in a rather scornful tone, "it means just what I choose it to mean, neither more nor less". L. Carroll, *Through the Looking Glass*. *Chapter 6*.

one's partner's speech may be normal in one place while failure to do so might seem slow-witted, whereas in another place, talking over the partner's speech might be perceived as highly disrespectful. People in different places and different roles in any one place will implement any particular protocol differently, but the difference between them in how they implement various protocols is likely to be consistent from one protocol to another. Indeed, it is the consistency of differences in how the protocols are implemented that leads the people to be characterized as "brusque" or "ingratiating". That consistency is their "norm".

The whole pattern of discriminable protocols defines a culture. As a language can drift and split, so can a culture. When we talked about sporadic collective control in Section III.1.6 we emphasised convergence when people interact, combined with separated convergent cores. We argued that if initially isolated people interact with each other non-uniformly, those who interact more frequently using a particular subset of protocols will form "gravitational" nuclei that form core structures for those protocols. These nuclei, by sporadic collective control will tend to draw in their neighbours, who will come to use them the same way as do the nuclear core.

"Massive" languages and cultures already exist, and people are born into them just as they are. Convergent drifts do occur, and are facilitated by the recent addition of technological proximity to physical proximity as a facilitator of interaction. I may interact more frequently with someone on the other side of an ocean than I do with a person who lives down the street, without even knowing whether an ocean lies between us. The problem that we must address is not why and how cultures converge, but how and why they split and become distinct.

One reason why cultures split was simply geographic distance and lack of interaction. We talked about this in Chapter III.1, and will again. But there is another reason, animosity, which we will examine later, when we talk about "Us and Them" in Chapter III.9. For now, however, we will deal only with one single converged "nuclear core" culture, and perceptual control by people who live in the culture.

III.6.7 Language and Culture as Malleable Artifacts

The title of this Section was the original working title for the entire book, so we must consider seriously whether language and culture ought to be treated as artifacts, in the same way as is a machine or a piece of jewellery. Accordingly, we return to the working definition of an artifact: *An artifact is perceptible by and susceptible to influence from humans, and exists in its current form only as the result of human perceptual control.* Are language and culture artifacts?

Language and culture are large structures. We have seen how small components of these structures, such as words, protocols, roles, and even entire social control loops are artifacts under the above definition. But are the larger structures?

We cannot provide a clearcut answer to this question without considering how to answer it for more tangible objects. We start with a window or a door in a house. They are clearly artifacts. They are designed and constructed by humans and may even be modified to fit the place for which they are intended. They wouldn't exist were it not for human perceptual control. Although they may be machine-made, the machine is only an atenfel that allows the maker to control their form more easily than could be done by hand. As opposed to a rock or a mountain, they exist for a purpose, and "purpose" is the very definition of a reference profile for perceptual control. Their purpose is to provide for a user an atenfel for control of some perception; the ability to provide the atenfel was a controlled perception imagined by the designer.

Move up a step in complexity, and consider the house itself. Unless the house is built from unmodified rocks found to hand, every bit of the house is an artifact in the same way that its doors and windows are. The house has a structure, a large pattern of relationships between floorboard, between walls and floors, between stairs and hallways, between doors and windows, between electrical wiring and the walls and floors within which the wiring runs, between plumbing and external supplies and drainage, and so on and so on. Are these relations artifacts? Clearly they are, according to the definition. But is the house?

What is the house but the pattern of relationships among its elements? Stacked on the ground as delivered from the factories, those artifacts are not a house. Nor are the relationships arbitrary. A door is not a door unless it is possible to open and close it, and to walk from one side to the other when it is open. Nor is it a door if the spaces on either side are empty. If a wall has one door, it probably does not have another connecting the same two spaces unless the spaces are rather long. Individually, many of the relations are arbitrary, and if different individuals were to decide on the reference relationships for each pair of constituent artifacts without considering the context of other relationships, the building that would emerge would probably not function (provide appropriate atenfels) as we would normally think a house would do.

However, it is also not true that the house necessarily is built according to some predefined reference pattern such as an architect's design blueprints, and when it is built, there may not be anybody who can perceive directly or through memory all the relationships among its parts. But the house can be modified if someone perceives (imagines) that changes could better match some perception to their reference value for it. A room can be added, a bare basement can be furnished, and these changes may even occur while the house is being built. Like the statue carved by Michelangelo, the structure of the house is an artifact independent of the artifacts of which the house is composed.

The issue becomes murkier when we ask whether a city is an artifact. Most cities, especially in the Old World, have no design in the sense that someone or some Giant Virtual Controller once had a reference profile for the pattern to which the city now conforms. Like the marble from which Michelangelo carved his statue, the city just grew from a cluster of houses to a village, to a town, and finally to a city. Its configuration certainly was shaped by perceptual control. Someone had a reference value to perceive his house *there*, someone had a reference value for placing water supply lines and drainage *along here*, and so forth. But these perceptually controlled components are no more the city than the doors, toilets, drywall and electrical outlets are a house. *This* house is *there* because that school was *over there* and those shops were close by when someone planned its location. The house is not where it is because putting it there reduced error in someone's controlled perception of the shape of the city.

It is, however, true, that houses may be destroyed, streets and transportation infrastructure built, and so on because to do so reduces error in someone's perception of the best shape for the city. Baron Haussmann re-imagined the street pattern of the centre of Paris, as to some extent did Wren for London after the Great Fire. So although it may have grown passively like Michelangelo's block of marble, it still can be shaped, just as Michelangelo shaped the marble.

In most cases. however, the shaping of a city is controlled much less than is the shape of Michelangelo's statue. Shaping the city involves more than modifying its visible elements. For example, the city government may agree to subsidize an opera company, an art gallery, or a hockey team, shaping the atenfels available to the citizens. We may say that the city's physical and mental shape is partly artifactual, and partly natural. But it is entirely malleable, in that any aspect of it that can be perceived also may be influenced by the actions of people controlling their perceptions.

These ways of shaping the city by perceptual control of some authority omit the major way cities evolve. Much more than because someone or some Giant Virtual Controller acts to alter the shape of the city, its shape depends on individual control of perceptions such as wanting to live near a school, or

overlooking a nice view, or within walking distance to shops, or of getting money by opening a shop in a region housing the kind of people the potential shopkeeper perceives as being likely to buy the wares. These changes compare more closely to mutations in an organism or to the development of novel control structures in an individual than to the sculpting performed to bring a piece of marble to a reference shape.

The city is an ecology that has some characteristics of an artifact. Ecologies are often analyzed as networks with links of different kinds, such as predator-prey or resource competitions. One might think of the relation between a shop and its customers as a predator-prey relationship, since if the number of customers declines, the shop might die. But the relationship is different, since the existence of the shop is more likely to increase the number of customers for its products in its catchment area than to decrease them, whereas the predator decreases the number of prey in its neighbourhood. The latter can lead to population oscillation or extinction of the predator, as described by the Lotka–Volterra equations, if the predator has only one prey species and the prey is a target of only one predator.

A predator-prey relationship might be considered to exist between an extortionist gang and the shopkeepers in a neighbourhood, but again the analogy is imperfect, because the equations assume that the predator kills the prey, whereas most extortionists, like vampires, control for perceiving their victims to stay alive. Nevertheless, despite these imperfect analogies and many more, the networks of relationships of perceptual control that define the physical and social form of a city seem well suited to the kind of ecological research that could not be done well without Perceptual Control Theory.

So where does that leave language and culture, which have no tangible components? Apart from "interior speech", language exists only to facilitate display in the execution of protocols. Every use of language is clearly artifactual in being the result of perceptual control. The instance is the output action of a perceptual control system, but its form is the result of collective control, the CCEV of a Giant Virtual Controller. Reorganization has created in the individuals who use the language control structures that work because of the existence of this CCEV. The form, the CCEV, is an artifact, and is part of "language", whereas the instance is an utterance or a gesture, a passing transient disturbance to someone else's perception.

Like a city, the language grows and changes. The changes of form are the result of collective control, and as we showed above, one drift of collective reference value can lead to another, the addition of a new concept or the splitting of an existing one can lead to further changes, just as with a city the building or closure of a school may lead to alterations in traffic patterns and the demographics of home ownership in the area.

Consider some of the examples mentioned in the introduction, thinking now of words as though they actively participate in their own use. For example, if "impact" means only a short, sharp, shock, as it did in my youth, then it does not allow for phrases such as "the impact of the population increase on food supplies", or a verb form such as "this choice impacts the students".

Of course, the word did not actively prohibit such usages and has now become more permissive; what has changed is the collective control that would then have disputed the use of "impact" for a slow effect or as a verb of any kind. Nevertheless, just as one says that "a thrown rock broke the window" as though the rock actively and intentionally did the breaking, so we can say without fear of confusion that slow changes in language use have "impacted" the contexts in which "impact" can be used, as though the language were an active controller.

Because "impact" has broadened the scope of its permissible contexts, those newly permitted contexts can also be said now to permit "impact". The relationship is reciprocal. A context in which "influence" would have been permissible, such as "the influence of the population increase on food supplies" now admits "impact". So do contexts in which "effect" and "affect" would have been used. "Impact" thus

begins to take on the function of a scope-limited pronoun and pro-verb meaning any generic influence, in the same way that “thing” represents an arbitrary list of objects and constructs. “Influence”, “effect”, “affect” and similar words still can be used when precision is required, but it is easier just to say “impact” than to choose the appropriate word, just as it is easier to say “the thing” rather than “the screwdriver”.

The convergence of the concepts “to influence”, “to affect”, “an effect”, “an impact” onto the one word “impact” as both a verb and a noun is one example of language drift,

Language is an aspect of culture, but culture is much more than just language. A culture can be delimited in many ways. There is the culture of a sports club or of the sport itself, of a family or of a nation, of a profession or a group of friends. One person may belong to many cultures, while speaking what is nominally the same language (such as “English”) in all of them. The sets or networks of protocols used in the various cultures differ, and hence the display forms of language will also differ. We call those different subsets of the nominal language “idiolects”, but that is unimportant in the bigger picture. There is more to a culture than the protocols.

Whereas “language” is the display component of all the protocols used or usable in a culture, the culture also includes inanimate objects such as statues, flags, building styles, family relationship patterns, government forms, likelihood of submission to authority, and so on and so forth. None of these are arbitrary. In one culture most individuals may submit meekly to a uniformed man, whereas in another, most individuals may be willing to ask the uniformed man why he is asking whatever he is asking. In one culture most of the flags have one pattern, in another they have a different pattern, and so forth. But in none of the cultures in which many flags fly are the flags of random patterns. We may extrapolate and say that what defines a culture is the totality of variables collectively controlled by those accepted as belonging to the culture.

Of course, as is so often the case when we deal with complex feedback systems, there is an element of circularity in this definition. If what defines a culture is the set of all collectively controlled variables controlled to the same value within tolerance bounds, and what defines the participants in that culture is their participation in that collective control, do we not run the risk of saying something along the lines of “All swans are white; that bird is black, and therefore it is not a swan”? No, we do not, because of the fractal nature we have already ascribed to the concept of culture. Earlier, we intuitively noted that different sports have different cultures, that the culture of one family may differ from that of another, that a man can belong to a wide variety of cultures, acting in one or another at different times, and that all these differences and commonalities result in major overlaps of “cultures”.

Now we have a PCT argument for why this is so. The overlapping cultures have no existence other than the fact that two or more people collectively control some variables without conflict about their reference values. When the same set of people participate without conflict in the collective control of a set of variables, the existence of these coincident sets defines a culture.

The culture is the set of variables collectively controlled, and the participants in the culture are the people doing the controlling. If the participants in the culture more commonly agree that most of the characteristics of that bird are those of birds we have called “swan”, then it is a swan than agree that “white” is an essential property of a swan, so that black bird is not a swan, either the two sets are beginning to create a language split, or the majority will control for it being a swan even when conversing with someone who says it is not.

Of course, such mappings of people and sets of variables never have clean boundaries. Some variables will be strongly controlled by many people, while other variables are controlled at low gain and with wide tolerance by fewer people. At some point in this degree of collective control, a variable will pass some arbitrary boundary and no longer be said to be a part of that culture. Likewise, a person who participates

in controlling only a few of the many variables of the culture may be said to not belong to the culture. The definition of who belongs to a culture and what variables define it is a matter of perception. The fuzziness of the boundaries in no way detracts from the clustering of people and sets of variables that define the cultures all the way from the special private cultures of twins to the general culture of a nation.

If “language” is founded in protocols, and “culture” is founded in Giant Virtual Controllers, is it still legitimate to consider language as an aspect of culture? Yes it is, because the forms of protocols and the forms of language that allow protocols to be effective are the CCEVs of collective control, just as are all the other elements of any culture. Language is a component of any culture that uses language, meaning almost all human cultures, and probably many non-human ones if we remember that “language” can include gestures and scents as well as words.``

Chapter III.7. Social Norms, Illusions, and World Models

Hitherto, we have mostly considered perceptions of the World as being based on observations that can be verified by comparison against other observations that "should" be related in some consistent way, or by attempting to control using them. Now we venture into less reliable territory, where perceptions are based on what other people say, either about the way the world is or about the way the world works.

We discussed figural after-effects in Chapter 8 in the context of visual perception. Now we develop the analogous notion in the context of social norms and anchors based on collective control. There are two kinds of "norm", what typically is observed and what a cultural Giant Virtual Controller controls for being observed. In this, normal speech on the one hand and dictionary-and-grammar-book language on the other are specific instances of "is" and "should-be" norms. Most of us accept that the things everyone around us says are true are indeed true, especially when we are growing up and learning about the world from these collectively controlled norms rather than from our lifetime experience in perceptual control of an increasing and increasingly varied set of perceptions.

III.7.1 Trust and Truth

In a sensory figural after-effect, the "truth" being explored is the relation between, say, the curvature of an arc or a tilted line, as measured by the experimenter, and the tilt or curvature as reported by a subject following exposure to a slightly curved arc or tilted line (e.g.Gibson, 1933, Gibson and Radner, 1937). Two things happen in the experimental situation. Firstly, as the inspection of an initially near-straight arc continues, it appears to become straighter. This phenomenon is sometimes called normalization or adaptation, and sometimes regression to the norm (straight being the measured norm, since on average the arcs we see in everyday life are biased neither to right nor left). The second phenomenon is an increase in the deviation of other arcs or lines away from the curvature or tilt of the inspected figure. All of these, and other more complex contextual effects discussed in Section 10.3, alter the "truth" of one's perception of the environment — the match between the perceived CEV and the RREV that is hidden in unknowable Real Reality.

The kinds of "truth" most influenced by social interaction are artifacts, created by multiple interactions with people who tell you things that affect your World Model. Most such "truths" are not testable by direct perception. If someone tells you that the sky is green, you can test it by going to look at it unless you are colour-blind or are confined without sight of the sky. On the other hand, if someone tells you that Arthur Milleson, who is known to you only by name, is a thief, it is unlikely that you have any way to test it either by direct observation or by using that truth as an atenfel for control of a perception not directly related to Arthur Milleson. You might control for avoiding hiring him as a contractor, but not much else.

If three people who belong to a group in which you are a member separately tell you that Arthur Milleson is a thief, his "thiefhood" is likely to become a perception and perhaps a belief, a truth for you. If you ever meet him, you may control a variety of perceptions that include "thief" as an input to their perceptual functions. You might, perhaps, hide your valuables if some day he came to visit. You might observe his actions more closely than you would observe those of another stranger. But since these three people all belong to the same group as you, it is quite likely that only one of them (if any) independently had evidence about Mr. Snitchowitz, and that person told the other two before they told you. Your trust in them may be justified by your common group membership, but your trust in what they tell might well be tempered by your knowledge of the "echo-chamber" effect, a frequent manifestation of a homeostatic loop.

Now change the situation a little, and instead of the three people belonging to a group of which you are a member, let us imagine that the three belong to a group of "*THEM*" who you perceive to be trying to make bad things happen to you. In that case, not only is it improbable that Arthur Milleson's "thiefhood" will become a truth for you, but you may perceive the members of the untrustworthy group to be controlling for you to believe he is a thief, rather than letting you know it as a side-effect of controlling some other perception. In that case, you might believe that "*If* those people *say he is a thief, he must be honest*."

If a deceiver wants to create a "truth", one way to do it is to have the mark perceive an illusory direct perception. An illusory perception is created by a perceptual function from "true" sensory input, but the result does not correspond to a state of the world as it would be perceived by other means. The illusory nature of the perception may be resolved by the kind of testing-by-control we have been discussing, but opportunities for testing are seldom available in the higher levels of the perceptual control hierarchy. To test the truth of a politician's claims by control is very seldom possible. Some people resolve this problem using the old adage: "*How can you tell if a politician is lying? His lips are moving*." Others trust some politicians but not others, but I suspect that few believe everything claimed by any politician.

A standard magician's trick is to have objects appear and vanish into thin air, at least to the viewer's perception. That trick is much used in warfare by the military. It was highly recommended as early as Sun Tzu (ca. 600 BCE), and was used to great effect as recently as the apparent "creation" of an entire Allied army in Kent commanded by General Patton, just across the narrow Pas de Calais from France. The Nazi High Command was intended to perceive this army to be preparing to invade France near Calais in 1944. The army, however, existed only in the form of realistic radio traffic and radio silence, plus some semi-hidden mock-up tanks and artillery designed to be seen by German scout planes. Hitler's perception of that non-existent invasion force persuaded him to delay sending powerful Panzer reinforcements to Normandy long enough to enable the real invasion of June 6, 1944 to gain a substantial foothold.

A classic example of illusory direct perception was used by Shakespear in his play *Othello*. The villainous Iago controlled for perceiving Othello to perceive that his wife Desdemona was unfaithful. One way to do this might have been for Iago to tell Othello that (un)truth, or better, to have someone Othello trusted tell him. Either way, Iago's control in imagination told him that Othello might fail to believe the (un)truth, so instead Iago placed Desdemona's handkerchief where Othello would find it in circumstances that Othello would perceive as likely only due to her infidelity, a direct perception "truth" that happened to be false.

To repeat a basic principle of PCT in this new context, the best test of "truth" is the successful use of the "truth" in controlling one or more perceptions. If it actually is an untruth, control is likely to fail. Truths of this kind, once tested in this way, are not artifacts, though they may have been created by people, because once tested they are relatively immune to further alteration. The next best test is passive observation, which is vulnerable to the magician's trick. Such truths may be artifacts, but a direct observation that the sky is blue rather than green probably is not.

Finally, we come to the truly artifactual "truths" that are perceptions of the world based on using other people as perceptual atenfels in the way one might use a tool such as a telescope to allow one to see what cannot be seen with the unaided eye. We see the world through the eyes of others, perceiving the world as it is transformed by the telling, in the way a general on a pre-industrial battlefield "saw" the flow of battle through a stream of messages provided by couriers.

Most of our higher-level perceptions of the world are likely to be formed this way — many people tell us different component things that we have no way to test, which we may perceive as truths if they do not conflict with other perceptions we currently have. We may use these components to build a truth that we

think we have created in an unbiased way, without perceiving the bias inherent in accepting the truths about the components that have been fed to us since childhood by others.

III.7.2 Is Truth an Artifact?

PCT recognizes that all we can know about the external world is embodied in perception, but what we know is not necessarily conscious, and even when it is, we may not be able to express it overtly. Much of what we know is embodied not in things we can speak about, but in the ways we act to control our perceptions, ways that were developed through variation of behaviour to control them effectively in our real reality environment, which includes our social environment.

We may well control some things better if we perceive to be true whatever the people with whom we communicate think to be true, and if in their use of protocols with us they control for us to show that we also believe to be true. This being the case, we may well ask: "What is truth?". Is what we perceive "true" about the real external world? How could we know? We may also ask: "*Does it matter*?"

Well, yes, it does matter. Nature is a stern teacher. If we don't see that there is a step down just ahead, we may fall and be severely hurt. If we walk through an area of intense nuclear radiation, we will not perceive it, but soon we will fall sick and die. If we are in the desert and walk to the lake we see in the distance, hoping to find water, we may die of thirst if the perceived lake was a mirage. If you perceive a tree branch to be strong enough to support a swing, and it breaks when someone uses the swing, your perception of the strength of the branch was not true. Truth is out there in real reality, and it matters.

The kind of untruth illustrated by these failures of control may be corrected by reorganization, at least if the affected state of the environment is available to the senses and the control error does not leave the controller incapacitated. The consequence is that most of your perceptual functions have developed through evolution or reorganization in such a way as to make your perceptions true enough that your perceptual control works in your normal everyday environment. If that were not the case, you would probably be dead instead of reading this.

We do not perceive nuclear radiation, perhaps because it never mattered to our ancestors whether they did or not. We can therefore take what we perceive directly to be at least provisionally true, despite the existence of mirages and illusions that sully the truth of our perceptions. These untruths can be corrected if they are used in control that fails. Such "truth" is testable.

"Who ya gonna believe, me or your own eyes?"

(Chico Marx, in the movie "Duck Soup")

There is another kind of "truth", which is exemplified by Chico Marx's question. It is the truth someone tells you, an artifact created by the informant, as we discussed in connection with the thiefhood of Arthur Milleson in Section III.7.1.

Just the place for a Snark!" the Bellman cried,
As he landed his crew with care:
Supporting each man on the top of the tide
By a finger entwined in his hair.
"Just the place for a Snark! I have said it twice:
That alone should encourage the crew.
Just the place for a Snark! I have said it thrice:
What I tell you three times is true".

(Lewis Carroll, 1876)

If you accept as true what you are told, you perceive it to represent a property of your environment. For the crew, if they believed the Bellman, then they would then perceive "this" to be "just the place for a Snark". "Just the place for a Snark" is a perception, and that perception would be a "truth" of the environment because the Bellman had "said it thrice". Saying untestable things many times is a tried and true trick of the politician's trade. No matter how thin the air out of which the statement was pulled, if it is told sufficiently often, many people will believe it. Apart from their perception of the trustworthiness of the politician, they have little evidence on which to base their inclusion of this possible truth in their model of "the way the world is."

Some members of the crew might have been a bit skeptical about this being "just the place for a Snark". They had a perception of the reliability of the Bellman's thrice told "truth". You perceive a level of "truth" for all perceptions; we call this perception "belief" as we discussed at length in Chapter 10. In Carroll's "The Hunting of the Snark", the Snark-hunting crew were able by chance observation to turn the Bellman's apparently untestable truth about this being a good place for a Snark into the tested kind of truth when the Baker found a Snark, one that unfortunately turned out to be a Boojum, and as a result ".. *had softly and suddenly vanished away*".

A truth tested by its effectiveness in control is not an artifact. If it is sufficiently tested, it may become a reorganized "truth" built into the structure of the perceptual control hierarchy. Indeed, we could turn that statement around and say that the reorganized hierarchy is an embodiment of the present state of a person's tested truth — at least of the truth of the way the world works and the truth of the structures of variables that have hitherto been controlled with beneficial results for intrinsic variables.

Tested truth embodied in the hierarchy is not perceptible by or influenced by humans in any overt manner. It exists only as the result of human perceptual control in a structure that has developed as a consequence of acting in a given environment. The reorganized and tested truth is contained in the set of perceptual functions that generate a value, given input from the sensory systems and imagination, together with the skills that allow the person to control those perceptions in the environment in which they have lived. The value of a controlled perception is influenced by the action of the controller, but the truth of that value is not. It is what it is.

On the other hand, if you are told something, your informant may or may not be describing something they have observed directly or tested in perceptual control. Either way, what you perceive is something your informant constructed or was told, not something you have tested. You may later test its truth by using that perception in control, or by controlling your perception of their construction, just as you might test the strength of a chair by sitting on it.

Almost always, you are unable to test whether what you are told is true of the world. For example, if I tell you that there are 167 different species of red-winged butterflies in the world, you might believe me if you also believed I was a noted entomologist (which I am not) or had recently read about it somewhere (which I didn't), or you might not believe me if you believed I knew nothing of the subject (and you shouldn't because it is a number I just picked out of thin air).

Whether you believe me or not, you are unlikely to use "167 different species of red-winged butterflies" as an atenfel for control of anything, so it remains untested. Perhaps it becomes a small part of your World Model of *the way the world is*, perhaps it does not, depending on the level of trust you have in things I tell you, or if, like Sherlock Holmes (Section II.13.7) you do not believe it is likely to help you control any perception you might want to control in future. If I tell you the same thing several times, it is no better tested than it was the first time, but you may perceive that I perceive it to be true. If you trust me, you may actually come to believe it to be true, and you are even more likely to believe it if several different people you trust tell you the same thing.

Earlier (Section II.13.2) it was pointed out that if I can control something about the way you perceive the world to be, meaning that I can trust you to believe something to be true, then I can treat my perception of what you believe as one of McClelland's stabilities that enhance my ability to control my perceptions. Increased ability to control my perceptions increases my "worth" (Section 6.2) or "power". Although what I have done is modify and stabilize a state in you, I am not in any way controlling your behaviour. But I may be influencing your likelihood of acting in certain ways to counter certain disturbances, and those ways might tend to be more to my advantage than the actions you might have taken had I not controlled for you to believe what I wanted you to believe.

We saw an example of this in the discussion of deceit and camouflage (Section II.13.10). The con-man who wants to take your money does so in part by putting a particular "truth" into your world model — that he is a friendly and honest man. He will be able to defraud you later because it is a general truth that will form part of your perceptions of his intentions when you observe his later actions. You are likely to believe what he wants you to believe, because you perceive him to be an honest man. Only too late (he hopes) will you discover that your perceptions of his self and his intentions were illusions. If the con-man is a politician, by the time you discover your error in having voted for him, he will be in office.

The truth someone tells you is an artifact, constructed by, perceptible by, and susceptible to modification by human action. The truth the crew members had about this being a good place for a Snark was, for them, an artifact created by the Bellman until the unfortunate Baker "softly and suddenly vanished away". At that point, it became a partially tested truth.

That fact raises once again the issue of "belief" and "uncertainty" perception, seldom considered in any depth in discussions of Perceptual Control Theory. Those individual perceptions of other perceptions are, however important for collective control, which depends on the relationships among the controlled perceptions of many individuals. We therefore must spend a little time returning to consideration of individual perceptual control, this time concentrating on the effects on what you actually perceive of what other people tell you.

III.7.3 Artifactual World Models

The perception of a symbol as "good" or "bad" is an artifact. It has no intrinsic truth in the sense that the perception of a plank as too thin to walk across does have an intrinsic testable truth value. A particular pattern of, say, red and yellow stripes is said in Madrid to be "bad", but in Barcelona to be "good. If in Madrid you act as though you perceive it as "good" such as by wearing such a scarf or waving a flag with that pattern of stripes, you may find yourself to be generally perceived as one of "them", a supporter of Catalan independence.

"They" often are said to be the source of all failures of control, whether "they" be supporters of a different soccer team or people who control for (or against) Catalan independence from Spain. The red and yellow stripe pattern is "bad" simply because people say it is, and act towards instances of that pattern as they would toward other things and people they perceive to be "bad". An intangible artifact such as the "badness" of an arbitrary pattern is likely to be the CCEV of a Giant Virtual Controller, a cultural norm.

As we discussed earlier, many of our perceptions are artifactual, being based mainly or completely on what we are told rather than what we observe and control directly. All the "facts" of science and religion are of this kind unless we do the research ourselves, something that is in principle possible in science though not in religion. Even then, when we do the research we rely for most of our procedures and observations on perceptions previously created as artifacts. Not many people have seen and manipulated individual atoms, but most now perceive the tangible world to be built from atoms. To test the truth of this

perception depends on the differential ability to control perceptions if it is true, as compared to it not being true, and most people cannot do that. They must "take it on faith".

Our control of our perceptions of relations with other people is a different matter. If all the members of Toby's community perceive the world to be made of atoms, but an adult Toby perceives that it is not and says so, Toby may be perceived as ill-informed. Other things he claims to be true may then be perceived as questionable. Toby's ability to control using protocols with other people may be compromised if his protocol partners do not trust that his perceptions of the world resemble their own. If Toby is a child, and had no perception of how tangible objects are built beyond what he sees when he looks at them or breaks them, Toby may be given a new perception, using the "What I tell you three times is true" procedure (Section III.7.2).

Toby may have problems in his interaction with other community members, no matter what his belief, if that belief differs from their collectively controlled belief. If he interacts almost exclusively with people who say climate change is a hoax, but from his own analysis Toby comes to believe it is not a hoax and says so, he may equally be perceived by his larger community as ill-informed and untrustworthy. As in the example of the world being or not being made of atoms, Toby's ability to use other, unrelated, protocols with people in his community may be compromised by his declared belief in a commonly disbelieved "fact" of the world. Other people's perception of his reliability is not restricted to the particular fact in question, but extends to his reliability in a wide range of contexts.

Alexandre Dumas provided a good fictional example of this "halo effect" in his novel "The Three Musketeers". At one point in the story, a beautiful but murderously vicious woman has been imprisoned under the watchful eye of gaoler who is a committed Puritan, because she had been able to seduce her way out of previous imprisonments. At first she tries to seduce this Puritan gaoler, a tactic that has proved successful in the past, but he is immune. Then she prays as though she were herself a Puritan when she thinks he will perceive her to believe herself unobserved. The gaoler then believes that such a God-fearing woman cannot be guilty of the crimes of which she is accused, and arranges to set her free. She also produces in the gaoler an artifactual perception that the Prime Minister is so evil that the only way to correct the error in the gaoler's controlled perception of "Authority" (which has a reference value that high Authorities should be of good character) is to assassinate him, which the gaoler does.

In terms of our discussion here, the woman has displayed what was needed for the gaoler to perceive her as "one of us (Puritans)" and therefore to be trusted when she provides artifactual perceptual values that another observer would perceive to be untrue.

Different cultural groups control their CCEVs to different reference values, which we will call "norms". Nettle et al. (2014) showed that after even a short visit of under an hour to different neighbourhoods in a city, student interviewers who filled out questionnaires immediately after the visit moved their norms in the direction of the norms for the neighbourhood they visited, becoming relatively less trusting of randomly encountered people after visiting a higher-crime neighbourhood. The same research group (Schroeder et. al. 2014) found that the actions used to control variables in a game also differed between residents of the different neighbourhoods.

As with the figural after-effects, the shift of perception occurred even after a very short exposure, and though the experimenters did not report whether the effect decayed, one might anticipate that the return of the students to their previous norms would be swift. The exposures provided anchors, against which the norms of the students shifted temporarily. One might expect that a longer exposure to the changed environment would result in a slower return of changed perceptions to their original values. If what I tell you three times is true, how much more true is what all my friends tell you thirty-three times? Especially if you have no way of testing its truth other than in interactions with me and my friends?

In other words, it should be difficult to switch from a culture in which you were raised to that of a place to which you move later in life. That was the insight of the Jesuits who wanted to be responsible for a child until the age of six. If you are in the company of people who believe that there is a pot of gold at the end of a rainbow, you may come to believe it, even though none of them can display the wealth they gained by controlling their perception of going to the end of the rainbow to collect it. You may even come to believe that their failure was due to their lack of faith in the reality of the invisible leprechaun who could grant access the the pot of gold.

III.7.4 The Tail of the Invisible Rabbit

If one has been told by most of the people one has met for the first few years of one's life that when one meets Mr. Dowd, it will almost always be in the company of a six foot invisible rabbit called "Harvey", one is likely to believe it into much later life, especially if one has often met Mr. Dowd and heard him talking to the rabbit and letting people know what the rabbit said. If the group collectively controls a virtual perception of the existence of a six-foot invisible rabbit that is a friend of Mr. Dowd, then some other perceptions will be controlled better if one perceives Mr. Dowd's rabbit to exist than if one doesn't, and few will be controlled worse.

Perceiving Mr. Dowd's rabbit to exist does not reduce one's ability to control other perceptions, except perhaps that as one gets older one may develop a perceptual conflict with a World Model that has no place for invisible rabbits that speak only to one person. Such perceptual conflicts are easily resolved if one perceives in another part of the World Model that the invisible rabbit also does not register on technological sensors. Its existence cannot be disproved by any conceivable test, and its existence is consistent with perceiving Mr. Dowd talking to it in the way he talks to any other person.

If one now moves to another town, away from the group of Mr. Dowd's friends who perceive that the invisible rabbit exists, and joins various groups of people who have never heard of Mr. Dowd, then to continue to perceive the rabbit's existence may begin to impede rather than enhance control. If one tells a new friend about the rabbit, the friend might make fun of the idea, perhaps disturbing one's self-image perception — "You think I am silly to believe that an invisible rabbit exists and actually talks to Mr. Dowd?" — perhaps instead altering one's perception of the other as being friendly —"Of course the rabbit exists. I know it does. How can you possibly say that it doesn't? Are you just trying to get under my skin with your silly comments?"

In the latter situation, we have conflicted collective control, both persons trying to control for both of them to have similar perceptions of the existence of Mr. Dowd's six-foot invisible rabbit, but at different reference values. As with any such conflicted collective control, the conflict can easily escalate if the difference is beyond the limits of their tolerance zones. Within the other's tolerance zone: "I don't care if you believe in your silly rabbit or not, so long as you allow me to believe there's no such thing", as opposed to (outside the tolerance zone) "There's no such thing as a six-foot invisible rabbit" "Oh, Yes, there is" "You aren't making any sense" "No, it's you who is making no sense"… and the friends wind up as enemies, both having their perception of "self as seen by others" disturbed while having no atenfels that would allow them to control that aspect of the self-perception profile while one World Model contains an invisible rabbit and the other does not.

Mr. Dowd's invisible rabbit can have quite a long tail. The child brought up to perceive it and to perceive as "truth" the perceptions based on what Mr. Dowd says the rabbit tells him may retain those perceptions for a lifetime unless they are superseded by the development of other conflicting perceptions. Even then they may revive if the conflicting perceptions are themselves suppressed. Just as with the

figural after-effects, the effect of a brief anchoring perception (a new idea, perhaps) is likely to decay away, returning the old "invisible rabbit" set of perceptions to their original status as norms.

III.7.5 The Convenient Myth

A Myth may be true or it may not. Mr. Dowd may actually be able to see and converse with an entity nobody else can see or hear, but apart from his own testimony, nobody can determine whether he actually perceives the rabbit with his eyes and ears, whether he has those perceptions but they derive entirely from his imagination or from some sense the rest of us do not have[33], or whether he only asserts he has those perceptions in order to control some other perceptions, such as his perception of the impression he makes on other people.

The historical existence of Troy used to have a similar character. Maybe the city mentioned by Homer and other bards once existed, but maybe it was a pure fantasy around which bards were conveniently able to fashion stories of heroes and gods. But unlike Mr. Dowd's rabbit, there are other ways of finding whether a city once existed, and the historical reality of Troy is no longer considered a myth because we are told that archaeological evidence is consistent with it having existed much as the *Iliad* says. Yet, very few of those who now believe that there once was a Troy have ever been to the place that is identified as having been its site. Of those that have, fewer still have seen the evidence that the city they visited was actually Troy, and of those, even fewer had the skills to be able to make their own interpretation of that evidence.

These last are in a position much like a person who has managed to create an instrument that allowed a skilled operator to detect a region near Mr. Dowd in which something other than normal air seemed to exist. These operators would be in a position to tell other people that Mr. Dowd may well have unusual senses and can see a rabbit where the instrument detects something unusual. The people they tell, however, have only the word of the operator that the instrument made a detection, and of Mr. Dowd that what the instrument detected was a six-foot invisible rabbit. Likewise, the truth of the historical existence of Troy, or indeed of any scientific discovery, depends entirely on trust in the teller of the tale.

I wrote: "*The truth of the historical existence of Troy, or indeed of any scientific discovery, depends entirely on trust in the teller of the tale*." But this is not entirely correct, is it? If the teller of the tale tells a truth that does not fit with what we already perceive to be in the world, or if it cannot readily be produced by our World Model, we may not include the tale among our perceptions of the way the world is or works, no matter how trustworthy we perceive the teller to be. We may change our belief in the truth-teller, and perceive that person to be honest but mistaken, and therefore less trustworthy than we thought earlier. We probably do not perceive the truth-teller to be untrustworthy in general.

Our model of the way the world works may not include the possibility that it includes an invisible rabbit that influences nobody's senses except those of Mr. Dowd. If that is so, then to perceive that Mr. Dowd really does perceive this rabbit requires us to greatly modify or discard many other perceptions. To perceive that the tale-teller made a mistake is much easier. Above, we treated this situation as a normal conflict based in collective control, but there is more to it than that. There need be no conflict at all.

In science, this kind of great modification and the collective discarding of other perceptions does happen occasionally. Einstein, for example, claimed that the apparent position of a star in the sky would be shifted if the sight-line was close to the sun, a phenomenon as unobservable as Mr. Dowd's rabbit until there was a total solar eclipse. He believed this because talking to his mathematical and intuitive muse

33. . In the kingdom of the blind, the one-eyed man is King. (Erasmus, according to https://www.brainyquote.com/quotes/desiderius_erasmus_161329, retrieved 2019.01.12)

produced a theory that said this would happen. When there was a solar eclipse, astronomers with accurate means of measuring the position of a star discovered that the star moved exactly as much as Einstein had told them it would.

At this point, anyone without such instruments or who had not observed the eclipse would be in the position of those who would or would not accept the word of an operator whose instruments detected something strange where Mr. Dowd said his rabbit was. Whether the star seemed to move had to be accepted or not, depending on one's perception of the trustworthiness of the observer and any intermediate communicators.

A historical side-note on this puts Einstein in the position of those who do not believe in the existence of Mr. Dowd's rabbit. Quantum Theory produced the concept of "entanglement", which is sometimes interpreted as requiring instantaneous communication between the states of particles separated by indefinitely large distances, or that small entities such as atoms and photons have no precise state until they are observed. Einstein refused to believe that entanglement could happen, and published arguments against it. Nevertheless, careful experimentation demonstrated (after his death, I believe) that it does happen, if one believes those who describe the results of their experiments and those who more widely communicate the results. In science, as in all else, your World Model depends on whether you can personally test the truth of a perception, or trust those who tell you what you should be perceiving.

As we said earlier, if a majority of the people in our environment assert that Mr. Dowd's rabbit really exists, it is likely to become one of our perceptions, on which other perceptions may be based. The rabbit becomes a part of our perception of "the way the world is" in our World Model. The fact that this perception was initially created not by direct observation but by interpreting the words of other people is irrelevant. We simply may come to perceive that the world includes this invisible rabbit. Even if we don't, we may pretend that we do when we interact with another rabbit-perceiver as a partner, so that we can use protocols that take advantage of the perceived existence of the rabbit, protocols that we could not use with people who fail to perceive the rabbit. By using these protocols we define ourselves as members of the "Rabbit-Perceiver" group, and enhance our trustworthiness as perceived by other members, something we may be controlling for. If these are useful protocols, the rabbit is a "Convenient Myth".

"Convenient" implies some worth, in that a convenient thing eases control. It is an atenfel, in the same way that smoothing a track eases control of perceptions that involve moving from place to place along it. The myth as atenfel need have no connection to anything that can be sensed. Nobody, even in the group of people who believe Mr. Dowd, has seen his rabbit, but all of them can use its properties in an interaction with another who believes Mr. Dowd's description of it having a blue waistcoat with brass buttons.

They could, however have a problem if they use that fact in talking with someone who believes that the rabbit's waistcoat is pink, to whom an expression such as "*The sky was as blue as the rabbit's waistcoat*" would sound annoyingly silly in comparison to "*His face was as pink as the rabbit's waistcoat*". On such untestable differences of perception do centuries of religious conflict depend.

III.7.6 The Child's World Model

It is said that the Jesuits claimed that if you gave them a child up to the age of six, they had that child for life. We offered in Section III.7.3 an argument by analogy to visual figural after-effects and temporary adjustments of social norms for why this might be true. Now we ask more directly: In what sense could this statement be true of the way the world works?

Throughout this book we have been discussing ways in which the structure of the control hierarchy can be influenced. We started by considering how reorganization of both the perceptual and the action side of the hierarchy allows actions on environmental variables to control perceptions in ways that keep intrinsic variables in safe states. We then moved to reorganization that allowed control through the actions of other people. Next we enquired into collective control that stabilizes environmental variables in ways that might allow them to become atenfels that could be used in the reorganization process. Most recently we talked of the development of World Models based not on reorganization in the process of control, but on being informed of the current state of the world and of the way the world works.

At this point the concept of the "truth" of a perception becomes important. Most of a mature human's control hierarchy is strongly influenced by the social environment in which the hierarchy had developed. The social environment determines the language that can influence the person's perceptions and the language the person can use to disturb perceptions in other people. The social environment determines what protocols will be available for the person to use.

A protocol for, say, buying an ice cream will not be available to someone brought up in a jungle tribe with neither money nor refrigeration, even when that person comes to the city and is shown an ice-cream van. A ritual for supplicating the goddess of the river will be of no use in a monotheistic or atheist community. The untested "truth" that you are told as a description of nature begins to matter less than its tested "truth", the truth that provides success in controlling perceptions during our interactions with other people. And that "truth test" does not depend entirely on the way physical real reality works. It depends to a greater or lesser extent on how your social contacts believe it works.

Whether the river goddess exists as a perception of the way the world is depends not on observing her presence, but on being told by various trusted people that she exists, and being able to use the perception that she exists in successfully controlling other perceptions in that community. Whether supplicating her produces the desired effects on the controlled perception might perhaps be testable, but having been told that this is the way the world works, the person is likely to perform the actions anyway, and impute failure of control to other unwelcome influences.

For example, if one day you catch no fish you may perceive that perhaps something you did has annoyed the goddess and she is retaliating. You perform the appropriate atonement ritual, and next day you do happen to catch some fish, so your perception of the river goddess tends to become part of your reorganized perceptual structure, and the atonement ritual part of your reorganized output structure. The following day, you again catch no fish, but you cannot think what you did to annoy the goddess. You must have done something, or so you believe, so you try the atonement ritual again. If it works, you performed it correctly. If it doesn't your sin must have been more severe, or perhaps you did the ritual wrong. If the ritual continues to fail to produce fish, perhaps others in the community annoyed her and you are just caught in the fire of her annoyance.

It is very difficult to destroy an artifactual truth by testing, and very easy to confirm it by chance, as the joke about keeping tigers away by throwing scraps of paper out of the window of a bus attests.

As a control hierarchy matures, its perceptions and ways to control them proliferate. New mechanisms to control a particular perception may work better and supplant old ones, but they do not destroy the old mechanisms. The old mechanisms may not be maintained and may decay away, their linkages being used for other purpoese, if they are never used in control, but at least for a while they will exist and be available if circumstances arise in which they are used again.

It is said that one never loses the ability to ride a bicycle so long as one is not injured mentally or physically, even if decades elapse since the last time one actually rode, though it may take a few minutes to recover one's old skill. An adult who moves into a community in which an unrelated language is

spoken does not lose the ability to speak her native language even after many years, though it may take a few days in her native land to recover full fluency[34].

So what did the Jesuits mean? van Rijt and Plooij (1992) found that a child begins to be able to perceive and control system-level perceptions at about 18 months, which means that already there is a substantial hierarchy below that level. However, this does not mean that the language-dependent ways of influencing further development of the hierarchy are yet usable.

Only when the child can use language in ways that allow World Models to contribute to perceptions in the higher levels of the hierarchy do these ways begin to have effect. The child may then come to perceive that the world truly contains things that do not directly influence her senses, such as perhaps distant relatives, good and bad people she has never met, unseen monsters under the bed, games played in distant countries, and so forth, perhaps including river goddesses. Later, the world begins to contain intangible entities at higher levels, such as political parties, electric fields, and deities, all of which become perceived entities because of the "truth" that "what I tell you three times is true".

By the age of six, many of these entities will have disappeared from the child's World Model, while others have been confirmed by many tellings and by the reorganizations that are consequent upon acting as though the perceptions are true, in a social environment in which most people also perceive those same things to be true, or at least act as though they do.

Reorganization that allows effective control is not necessarily related to any truth of the non-biological world that an omniscient analyst would perceive. All that matters for reorganization is that perceptions are controlled in ways that keep intrinsic variables in good trim. As we have seen, group membership is often very helpful in this regard, as a group member can use the group's collectively controlled CCEVs as components of controlled perceptions or as atenfels for controlling perceptions.

III.7.7 The Stability of Norms

A concept important for perceptual control, which we have mentioned a few times above, is the norm, a state of a perception that is stable enough to be used as a reference for the purpose of perceptual control. Most of the time, most things you see do not move (much) with respect to each other. Walls and floor maintain a fixed relationship perpendicular to each other. The house next door remains the house next door until it is accidentally or deliberately demolished. Trees and leaves may move in the wind but they move only back and forth about a fixed position, unless the leaf falls off or the tree falls down, either of which is an *event*, a deviation from the norm. The stabilities described by McClelland in the extended quote (Chapter II.4 introduction) also can be seen as norms. Others can take advantage of those stabilities to enhance their ability to control — their individual and collective total "worth" (Section 6.2).

Kinaesthetic perceptions of the vertical and horizontal relative to gravitational and motional acceleration are quite stable over a lifetime. They can be used to determine when things are a little off vertical or horizontal, but the visual perceptions of vertical and horizontal are more labile. They change when you are dizzy, they may change if you put on spectacles, they may change when you go into a funhouse room with sloping floors and walls, and they definitely change if you put on prism spectacles.

The norm of "stationary" may seem self-evident, but the visual field is anything but stationary, even ignoring the movement of the eyes in the head, as one moves around controlling one's perception of one's place in a (perceived to be) largely stationary world. On a ship, for example, the "stationary world" of the ship's hull and superstructure moves in relationship to the gravitational vertical, and the gravitational vertical moves in relationship to the visual vertical. These shifts of what one normally expects to be stable

34. As my Korean wife, a trilingual psycholinguist, can attest from her own experience.

relationships all involve non-artifactual "truths" that are testable by use in the control of perception. Most people at sea gain their "sea-legs" after a few days of walking around while experiencing the motion of a particular ship[35].

What do norms have in common? One such property is stability over the time-scale of perceptual control. A norm is something one can *use*. It can be an atenfel in the same sense as McLelland's collectively stabilized CCEVs (in the introduction to Chapter II.2) can be atenfels. More to the point, however, although many perceptions are stable, only relatively few demand to be called a "norm". These are properties that remain the same in several contexts. They are thus atenexes that provide atenfels for control of many different kinds of perception, as do perceptions of horizontal and vertical. Of course, there is no firm boundary to determine whether a particular stability should be called a "norm" in control of any particular perception. Some stabilities function more often and more strongly as "norms" than do others, and it is a matter of no practical consequence which ones are provided with the label.

If the same departure from the norm is perceived several times or for a prolonged duration, as when an experimental subject views an inspection line tilted slightly off vertical, it can serve as a secondary norm, or "anchor" against which another presentation can be seen as a deviation, at least while it remains present, and perhaps for a time after its disappearance. A "norm" or "anchor" fixes a set of values of features in the perceptual space, so that the space in its neighbourhood is perceptually expanded (Taylor, 1963).

A norm is fixed for a long time, possibly permanently, whereas an anchor depends on recent off-norm perceptions that have been stable for some sufficient but short duration. An anchor either decays or is superseded over a relatively short time. Two nearly identical items such as synx locations are more readily discriminated as different if there is an anchor nearby (provided they are not confused with the anchor itself) than they would be far from the anchor. "What I tell you three times" can become such an anchor.

Both norms and anchors provide stable reference backgrounds or "frames" for other perceptions. When there is an anchor, a related norm often is also present in the context of the current perception. Deviations from either are easier to discriminate than those same displays would be in the absence of the norm. In simple visual perception tasks, test displays are seldom presented in an otherwise empty field. The frame allows the actual display to be seen as a departure from a norm, rather than as a simple absolute perception *sui generis*.

III.7.8 Cultural Norms and Anchors

Some quite complicated norms seem to develop in individuals quite early in life. Stahl and Feigenson (2015) refer to "hundreds of studies [in which] infants respond when basic expectations are violated", and give as examples the apparent passage of a solid object through a wall, the appearance of an object in a place other than where it was hidden, or of its disappearance from the hiding place, violations of number conservation such as 5+5=5, and, of more interest here, "when a social entity approaches someone mean rather than someone nice". In their study of 11-month-old preverbal infants, they found that the infants learned new properties of an object that had violated expectations better than they learned new properties of an object that conformed to what an adult would perceive as the norm.

Norms and anchors are perceptions of the state of the outer world against which more immediate perceptions can be compared, norms being longer-living than anchors. For some norms and some people,

35. Admiral Nelson, the hero of the Battle of Trafalgar, never gained his sea legs, but suffered from seasickness all his life (Nelson's letter of October 1804 to the Earl of Camden <https://www.bbc.com/news/uk-england-20662931> retrieved 2020/09/21.)

they may act as reference values for what the person should perceive. Some norms are enforced by a Giant Virtual Controller, in the sense that a person controls better if they are used as reference values for controlled perceptions, and some "enforced" norms have the form of laws. Most that interest us do not. They are simply perceptual regularities that create surprise when a perception deviates from them. This is the kind of norm that we implicitly discussed without using the word in our discussion of what's missing or wrong, and of surprise in Chapter I.10. The infant may see as "normal" that objects do not pass through walls, and that people approach nice rather than nasty people, but may not necessarily control for not perceiving itself to be passing through a wall or for not approaching a nasty person.

As we have seen, the relations of perceptions to norms and anchors come in different levels of truth-testing:

1. the perception is tested by attempting to control it, or by using its environmental referent as as an atenfel for controlling another perception,
2. the perception is a direct but passive observation of the exterior world, or
3. the perception is based in part or whole on a report by another person.

Now we look a little more closely at the last possibility, in which information about X is filtered through another person or persons to create one's perception of X, which one cannot observe directly. Mr. Dowd's invisible rabbit is the type example of this, but it can come in much more mundane forms.

The most straightforward instance of "filtered perception" occurs when someone else reports a state of the world they obtained by direct observation:

Helen: *Joe, can you look and see if it is still raining?*

Joe: *No it isn't, Helen. I don't see any raindrops in the puddles*.

Helen now has a perception of the outer world state, in which it is not raining. Of course, Joe might have been lying, but Helen can test the perception's truth if she wants, by looking out of the window. If she perceives Joe to be trustworthy based on previous experience, her belief in the truth of the raininess of the environment will be at a high level, and she probably will not act to check.

Not all reported states of the world can be directly tested by the person receiving the report: "Joe, how far is it from New York to New Delhi?" "7800km, Bill, — or maybe that is miles". By asking the question, Bill acts as though he perceived Joe to be an Authority (though he might actually be controlling a perception of the trustworthiness of Joe as an Authority). Bill cannot test the truth of the perception of 7800km as the distance between these cities by observation. The nearest Bill can come to testing it is to ask another Authority, such as Jill, who tells him that the distance is, but it is just a guess, 10,000km. By asking on-line Bill will get an answer of 11,778km (Figure III.7.1).

Bill has no way to test the truth of any of these answers, as he cannot perceive the distance directly, and unless he has some access to mapping operations, he has no way to influence his perception that does not involve other people. So what will be his perception of the aspect of his environment that is the distance between New York and New Delhi? And what will be his perception of the truth value of that perception — his level of belief in it?

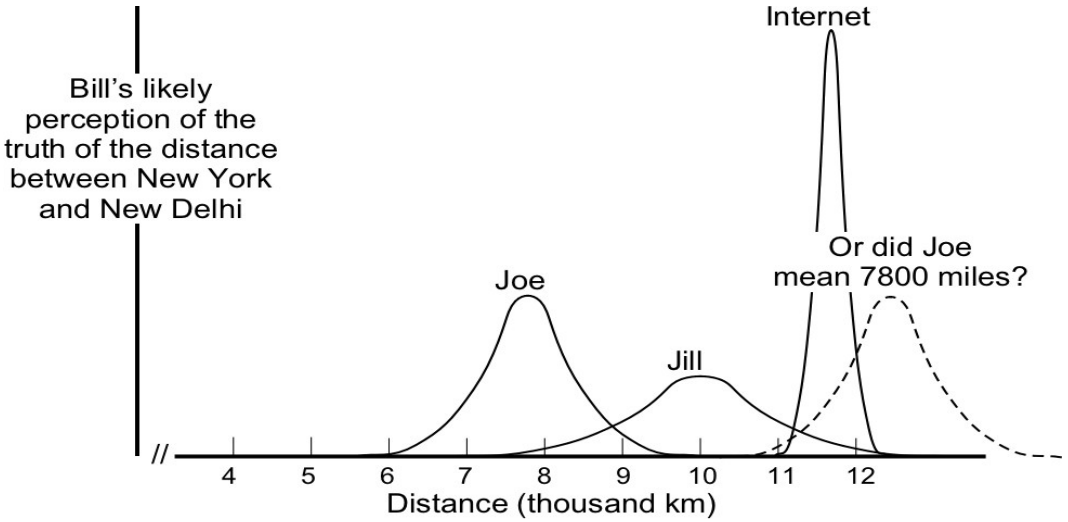


Figure III.7.1 Perceived "truth value" of distance between New York and New Delhi, based on the estimates provided by different Authorities as though each was the only available source of information on the subject.

Bill probably would not perceive that the distance was exactly one of the provided answers. Indeed, Jill remarked that her number was only a guess, and Joe did not indicate his level of expertise on the subject. He remembered "7800" from somewhere, but not the unit of measure. The Internet, however, provided a more precisely defined number, one that had been subject to stochastic collective control. "Collective control" means that it had been the CCEV of individually controlled perceptions, and would probably have been altered if some of the controllers had perceived it to be substantially untrue. Bill's perception of the truth of the distance will be some kind of composite of the answers he got from the different sources.

Of course, for Bill, "the truth" is a macrostate, the size of which depends on what perception he is controlling that requires the distance as input. For some perceptions, such as if Bill were choosing whether to go to New Delhi from New York by car or by plane, the answer "*Thousands of kilometres*" might be accurate enough. For others, he might need considerable precision. How he treats the different answers will depend on whether his macrostate includes distances to within 5000km or 50m. For the moment, we will continue assuming that Bill's tolerance macrostate is small compared to the distribution of answers he is given.

Suppose Bill asked several people, all of whom he would expect to know the correct answer, and they told him "About 12000 km" "11750 km" "11800km" "11800km" and "11770km". From those answers, without testing the truth of his perception, Bill would be likely to perceive that the distance was probably around 11800 km. He probably would consider Joe's "7800 km" as an aberration, but not if Joe had indeed misremembered and meant instead 7800 miles (about 12500 km).

The answers were not identical, but they were close enough that they could be taken to represent a true value near their average. "What I tell you three times is true" applies with even more force if different people do the telling, because informationally a second and third telling by the same person provide little or no extra information or reduction in uncertainty, whereas apparently independent information from different persons is additive. "Apparently independent" (perceived to be independent) is critical here, as we noted when we talked about whether Arthur Milleson was a thief.

This "composite answer" from apparently different sources is at the heart of the figural after-effect theory that allowed the two-parameter fits with the same pair of parameter values to so many different figural after-effects, followed by zero-parameter fits to two others. It will be central to our continuing discussion of the artifactual nature of language and culture. In the figural after-effect, the inspection figure is like the repeated "telling", increasing the discriminability of distances in its neighbourhood, and thereby reducing the uncertainty about the value of the test figure while perceptually displacing it with respect to the anchoring inspection figure. In all these cases, we are once again talking about Stochastic Collective Control.

Always, the "truth" of a perception depends on its use in perceptual control. If control works using the perceived value, the perceived truth of that value is enhanced, and if it does not, that perceptual value probably is not true of the environment. "The environment" in this context is not the entire external Universe, but is just the feedback path that completes the perceptual control loop.

In particular, the relevant part of the environment may be social, in which case the truth of the statement about the physical world may be irrelevant. Mr. Dowd may "truly" have no invisible rabbit companion, but in the social group that believes he has, perceiving the rabbit is truthful in the sense that it provides an atenfel for controlling some perceptions.

As we just noted, the perception that is tested may not be of the immediate object of control, but may be a perception of an atenfel for control of a different perception. The atenfel might represent an opportunity (Section 6.1), such as a perception that placing a plank across a brook would enable crossing the brook dryshod. In other words, the organization of the World Model is subject to the same issues of "truth" as are the current values of perceptions.

III.7.9 Superstition: The Cultural "Truth" of a World Model

A "filtered perception" might not be of "*the way the world is*", like the distance to New Delhi, but might instead be of "*the way the world works*".

"*Joe, what happens if we wrap sodium metal in a foil of potassium metal and throw the lump into warm water?*" "*That's a lot of fun, Bill. The lump floats around with a purplish flame, and then explodes, throwing little bits of burning sodium all over the place, like a fireworks display. The sodium bits sparkle on the lawn when you wet it down with a hose for safety after the explosion*"[36] This does not affect Bill's perception of the state of the world, which may or may not have potassium foil or a lump of sodium metal handy, but is a contribution to Bill's World Model of the way the world works.

As with the issue of perceiving whether it is raining, Bill could test the truth of Joe's description of the way the world works, if he could get his (gloved) hands on some metallic sodium and potassium, and a bucket of warm water, but otherwise his perceived truth of that particular way the world works must depend on his perception of Joe's trustworthiness.

Let's try a different example: "*Joe, what happens if we don't go to church on Sunday?*" "*That's no fun, Bill. The proctors will come on Monday and put you into the stocks and people will throw rotten tomatoes*

36. This actually is true. It is a ritual my father used to call "The Sodium Ceremony" that he performed when he had one of his rare reunions with a particular old high-school friend. They did it at night on a pre-watered wide lawn, and hosed the lawn down afterward to create a field of yellow-orange sparkles from the fragments of sodium metal. It is not a particularly safe ceremony!

at you." Joe's description of this aspect of the way the world works is just as testable as is his description of the effect of putting potassium-wrapped sodium in warm water.

Whereas a test of Joe's first answer will have the same result wherever and whenever it is tried, a test of the second would have very different results in different times and places. Whatever the result, the effect of "not going to church on Sunday" is a testable aspect of the Real World of the culture to which Bill (but perhaps not Joe) belongs. Nevertheless, if Bill trusts Joe to tell the truth, "*in the stocks being pelted with rotten tomatoes*" becomes a part of Bill's model of the way the world works when one does not go to church on Sunday.

Bill probably tries to avoid testing that truth, by controlling for being seen in church every Sunday. He never gets pelted with tomatoes, rotten or fresh, and never finds out whether Joe was telling him a truth about the way the world works or just passing along what Joe believes to be a truth, having been told it by someone else. Bill cannot even tell whether the whole story of stocks and tomatoes was something made up on the spot by Joe when Joe asked the question. Bill could find out whether Joe was telling a truth about the way the world works, simply by missing church one Sunday, but he probably controls for not finding out from personal experience of the physical environment. Joe's word is good enough, if Bill perceives Joe to be moderately reliable.

In discussing the control of atenfel-perception relationships, we have so far mostly used examples of tangible environmental objects that provide the atenfels, such as a plank to cross a brook or a cutter to sever a tree branch. But there is no need for an atenfel to be tangible in a social relationship such as a protocol exchange. Consider: "I*f you talk nicely to the shop clerk, she may try to find you just what you want*", as opposed to "*They probably have what you want, but you won't get it because they keep it for special customer*s". "Talking nicely to the shop clerk" is an intangible atenfel, which can become part of the shopper's World Model. The "truth" of that part of the World Model can be tested by going to the shop and "talking nicely" to the clerk, just as Bill could, in principle, test what Joe says about missing church on Sunday by actually missing church one Sunday.

Of course, without in some way using the Test for the Controlled Variable, the shopper would not be able to determine whether the clerk actually tried to find the elusive item or merely acted deceptively to make the shopper think she did. However, if the sought item is found, the "talk nicely" atenfel may become a stable part of the shopper's World Model, even though the clerk might actually have looked for the item however she was approached. Superstitious behaviour is easily sustained, if the opposite behaviour is never used in the same contexts. Consider the old joke:

Stan: "Jack, why are you throwing those torn scraps of paper out of the window?"

Jack: "It keeps the tigers away".

Stan: "But there are no tigers here."

Jack: "See, it works."

The "truth" is not assured of the "talk-nicely" atenfel's usefulness for controlling the "getting what you want" perception, even to the degree that the truth of "use a lever to move a big rock" is assured by successful control of moving one rock using a lever. Initially, it is, so as to speak, on trial as a part of the control hierarchy, as initially were all the components developed in direct control of things like moving rocks. If it works on several occasions, it is likely to be retained; if it usually fails, it is likely to be reorganized out of existence.

Superstitious behaviour usually works, because the perception it controls is normally at its reference level and failure to control it when it exhibits error can usually be attributed to other issues. In the manner

of its incorporation into the ever-changing control hierarchy, it can be just the same as any other reorganized parts of the control hierarchy, despite initially having been a pure artifact.

We find ourselves now at the interface between formal and informal organizations. Informal structures are based on affinities, whereas formal organization are defined by differences at many levels of organization. One is or is not a member of a formal organization such as a Club, a professional society, a Parliament or Congress.

The distinctions between formal and informal organizations are not always clear. Formal organizations have artifactual rules, either written or collectively controlled in a way we call “convention”. Either way, their structures and rules of membership and non-membership are accessible to individuals as properties of their environment within which their access to atenfels for controlling their perceptions is constrained more precisely than it is for informal organizations. All the same, formal organizations in which the rules are conventions are not easily distinguished from their ancestral informal organizations. Such boundaries are in the labelling, not in the reality that is labelled.

First we deal with a topic at the interface between formal and informal organization: Trade, and the Trade motif of perceptual control. Trade requires that the traders collectively perceive a relationship of “ownership” between some entity and some controller. Different cultures have collectively controlled different concepts of ownership, ranging in one dimension from extreme “Capitalism” in which everything is owned by specific individuals to extreme Communism, in which nothing being owned by individuals. We will leave discussion of the forms of organizations until after we have discussed a few more underlying topics: Trade, Money, Ownership, “Rattling”, and the difference between a person and the roles that person may play. We return to formal and informal organization in Chapter IV.1.

Chapter III.8. Ownership, Trade, and Coercion

In the last two Chapters we turned to a consideration of intangible artifacts of culture, and how the forms of these artifacts may drift or be deliberately modified over time, since they have no necessary relation to properties of material Real Reality, but can be continually reorganized to maintain a useful fit with social Real Reality. In this chapter we deal with the abstract concepts of "ownership" and money.

In many, but not all, cultures, a collectively controlled social norm is that some things can be owned, either tangible like a car, or intangible such as fishing rights on a river or the right to call oneself "Doctor" or "Engineer". To own a thing may be perceived differently in different cultures, but one aspect of ownership is always that the owner has exclusive rights to use some of its properties as atenfels. In many, perhaps all cultures, there are some things than cannot be owned, such as the right to breathe the outdoor air. Something that can be used by many but owned by no individual is called a Commons, the subject of the next Chapter.

Money is an artifact that to many people seems quite tangible in the form of coins and pieces of paper, but from the viewpoint of PCT money is as intangible as the structure of a language. The coins and pieces of paper are not money. Instead, they are words of a language in which concepts of money are communicated. Money itself is a language in which concepts related to ownership and worth (ability to control multiple perceptions accurately) are communicated.

When we think of behaviour as the control of perception, value of a dollar is simply the value to a person of the perceptions the money allows them to control. The value of a dollar is not "a dollar", a quasi-physical property like the weight of a coin in grams. The value to Katrina is how much difference she imagines it to make in her ability to control a perception she wants to control.

The same is true of "ownership". Something about owning an object or a right such as the right to fish in a certain river allows Katrina to control perceptions she could not control if someone else owned it. The value of a dollar, an object, or a right is a perception unique to Katrina. That value is the difference in her perception of her "worth" (Section 6.2) between owning and not owning these things.

We set the stage for dealing with money by talking about different kinds of intangible artifacts that become parts of similar world models inside people who have some common background. This common background helps them to trust as true what each other states to be a truth, so that they come to believe similar things about parts of the world that they cannot directly test by active control. The World Models of the people within such groups, large or small, will tend to converge and to be the objects of collective control. They may, however, differ from the World Models of people who come from other backgrounds or who inherit their reference values from a different branch after a Schism (Section III.3.7).

III.8.1 The Meaning of Ownership

Jake wants to be on the other side of a brook, but he does not want to get his feet wet. He sees a plank that is long enough to stretch across the brook, and looks strong enough to support him. Jake perceives that Sam owns the plank. In order for Jake to use it as an atenfel for perceiving himself on the other side of a brook, he must be able to move it so that it crosses the brook. He needs at least three properties of the plank (its location, its width, and its strength), but not all of them. He perceives the width and strength of the plank to be within the tolerance zones of their reference values, but its location is not. Jake must act to move the plank, but Sam owns it.

That may be difficult. Maybe Sam wants the plank to stay just where it is, for some reason private to Sam, and in Jake's concept of ownership, the fact that Sam owns the plank means that Sam has an

exclusive right to determine who can make use of its location property, which means to Jake that only Sam has the automatic right to control a perception of the plank's location. Jake therefore perceives that Sam has been granted or has inherited the authority to exclude Jake from his list of people who are allowed to move it.

Why Sam might not want Jake to move the plank is irrelevant, if in their culture to "own" the plank is to have the collectively controlled right to determine its location attribute. To determine the value of an attribute such as location is to be able to control a perception of the value of that attribute. Sam perceives that he has the right to control that perception, and a "right to do something" is an atenfel stabilized by collective control, perhaps through the performance of a ritual (Section III.3.3 and Section III.3.4). Jake can perceive that the same collectively controlled stability — the "ownership" relation between Sam and the plank — is not available to him. Following this line of thought, we can make a first assertion: that "ownership" implies a collectively controlled stability, the owner's permission to use the object as an atenex.

Does it follow that to own the plank gives Sam the collectively controlled right to prevent Jake from using any particular one of the atenfels available from this atenex? Sam would probably not object if Jake wanted to use the plank to show Julie a colour or texture he wanted to match in something he was building, because an unlimited number of perceptions that use observation of the plank's surface could be controlled simultaneously. Showing it to Julie in no way compromises Sam's ability to use it however he wants. Jake's use of the plank to cross the brook might prevent Sam from using it to stand on while painting his house, but Julie's looking at the plank does not. Does Sam's ownership imply that Jake cannot show it to Julie without Sam's permission? That will depend on the particular culture, and what rights are included in "ownership".

Here we have a beginning of a different approach to ownership. Anything that can be owned is either an atenfel, such as the right to fish in a certain river segment, or an atenex that makes available many atenfels, such as an entity or a physical object. If it is an atenex, as are most material objects, then in some culture what atenfels may be used only by the owner? The answer may not be categorically precise, but we can suggest that the likelihood of a particular atenfel being included in the concept of "ownership" may depend on two things: the category of the atenfel in the mini-taxonomy of Section 5.5, and the probable effect of the disturbance caused by someone else using the atenfel on the owner's ability to control — the owner's total "worth".

These are not unrelated. Someone else using a Catalytic Unlimited atenfel may not change the owner's "worth" at all, whereas someone else using a Resource Limited atenfel may change it drastically. Julie looking at the colour of the plank probably does not disturb any of Sam's controlled perceptions, whereas if Jake burned the plank and used the heat produced, that would eliminate all the other atenfels that were previously available to Sam, the owner.

What does it really mean to "own" X if X is an atenex, as is almost every material entity? "Ownership" of the plank is a relationship perception both Jake and Sam have and collectively control, quite apart from the community collective control of the ownership relation between the plank and its owner. Someone may own a piece of land from which a wonderful vista can be seen, but nobody can own the view from that place. The view is available to anyone who can manage to reach the viewpoint. The owner might be able to prevent access, but could not prevent a stranger who reached the viewpoint from enjoying the view.

If "X" is a piece of land that Joe owned and has agreed to share with Bob, they have the collectively controlled right to its atenfels, but clearly not an exclusive right to all of them. Not only is the view

available to anyone who can get to the viewpoint that is part of X, but so is the oxygen generated by all the plants growing on X. Ownership includes, and perhaps is limited to, to determine who has the right to use a resource-limited atenfel provided by X, and when. It is the right to exclude.

Different societies have different ways of treating owners' rights, ranging from the extremes of a Communist collective, in which nobody can exclude anyone from using any atenfel beyond the fact that they are currently using it, to the opposite Capitalist extreme in which the rights to everything, even the water we drink must be owned by some individual entity who is entitled to exclude anyone from using it.

For now will deal only with cases in which all parties agree — collectively control a perception — that a particular thing is or could be owned by a particular person or collective. Later in the book we will consider cases in which different collectives conflict over controlled perceptions of ownership.

III.8.2 Ownership Empowers Money

After language, the most important infrastructure invention for easing control is probably money. Money is a uniquely human construction, an artifact. So far as I know, no money exists in the non-human world, and none existed even during most of the two or three hundred millennia that have passed while humanoids walked the earth. It is a very recent invention in the long history of life on this Earth. We examine the concept of money using mainly a PCT Analyst's viewpoint, a viewpoint that allows us to observe not only the overt actions, but also the controlled perceptions of the people concerned.

The amount of change in the ability of an individual to control her perceptions is not the value of which we usually speak when we talk of the value of a dollar. We usually talk about the value of a dollar as real thing about which we can be right or wrong, an externally defined quantity, used by traders in currencies, by people who set prices for merchandise they want to sell, by unions and company contract negotiators in setting wages, and by almost everyone in an industrial society.

You can read such values in print or on-line, or be told them by a broker. As we shall see in detail starting in Section III.10.4, the externally defined value of a dollar is a CCEV controlled collectively by the totality of their individual trading actions, whereas the perceived value of a dollar is something unique to each person. A multi-millionaire probably perceives a dollar as having a much lower value than does an impoverished person wondering how to feed her children.

An essential property of an artifact is that its perception can be controlled, whether individually or collectively. Money, then, is an intangible artifact, one of many that together build the complex artifact we call a culture, just as the tangible artifacts called "bricks", "concrete", "planks", "glass panes", and so forth combine to form the complex artifact we call a "house". In the cultural "house" money might be the "cement" that holds it together, or lets it fall apart if the cement crumbles. A better metaphor, however, might be that money is the electric current that runs in the wires connected to our houses and factories, keeping our culture alive.

Just as the electric current powers our houses and industries, so does the collectively controlled perception of who owns something power our economic culture. If it is not collectively perceived that Judy owns a house, she will not be able to trade the house ownership for money (or even barter it for something else). Ownership, then, might be compared with the wires that carry the current. Without some concept of ownership, there is no use for a concept of money. Wires, on the other hand, can be used for other things than carrying electric current, and transactions in which ownership changes can be executed without using money.

The collectively controlled value of money is determined by what goods and services various people are prepared to provide in exchange for how many dollars, averaged over a network of myriads of

individual transactions. Each individual transaction influences the subsequent value of a dollar in later transactions, just as each pebble hit influences the location of the Puck in the stochastic collective control gedanken experiment of Section II.12.2. A transaction involves a change of ownership, itself an intangible artifact.

Ownership is a perceived relationship between an owner and a thing owned, and like any perception, it could be an illusion. We ask "perceived by who?", and we answer "perceived by anybody", but, importantly, often by a Giant Virtual Controller sometimes called "the law". Two old adages relate to ownership and law: "Possession is nine-tenths of the law", and "The law is an ass". The first suggests that questions of ownership can create a variety of different conflicts, while the second suggests that the law sometimes does not agree with collectively controlled perceptions of rights and fairness. Perhaps looking at the issues through a PCT lens might be a way to reduce, but certainly not eliminate, the complexity that leads to the law being an ass.

III.8.3 Shared Ownership and the Commons

Ownership of something implies the authority to exclude others from using as atenfels some or all its properties. Many kinds of things are owned by an individual. Some are not. The view of scenery from a particular place is one we have mentioned that is not, although authority to exclude people from reaching that place nay be. Nobody can prevent a person from seeing the view if they can manage to reach that viewpoint with their senses intact. The view itself is an undepletable resource, though the scenery viewed may change over time.

There are, on the other hand resources that can be depleted rapidly, such as the minerals in the Earth, which either were incorporated in the formation of the planet or were constructed by geological processes over time-spans very long compared to the lifetimes of people or even of civilizations. These are limited resources, and individuals (or corporations) usually assert that they own them, and are given authority to exclude others from extracting them from under defined regions of the Earth's surface.

There is also a third kind of resource, one that can be replenished while it is being used. The grass in a meadow grazed by cattle is such a resource. When different cattle herds with different owners graze the meadow, we have the situation that Garrett Hardin discussed in his seminal paper "The Tragedy of the Commons" (Hardin, 1968). This situation forms the foundation for this Chapter.

The kinds of stabilities mentioned in the quote by McClelland (LCS IV) in the introduction to Chapter xII.1 are mostly maintained by the perceptual control actions of Giant Virtual Controllers, so that they can be used as atenfels by unspecified persons for various purposes at unspecified times. These stabilities are a form of Commons that we have already discussed, but they will frequently re-appear in different guises in what follows.

In Chapter II.3 to Chapter II.5, we discussed the concentrations of simple and complex structures in a "soup" that might be constrained by a conceptual or material semi-permeable membrane. The "soup" is a Commons available to processes that have access within the membrane, if a membrane exists. It will be important when we discuss the Commons of Ideas. For example, the "soup" might be the ideas to which this author has access during the writing of this book. To a large extent, the ideas accessible to me are limited to those outside the paywalls (membranes permeable only to subscribers) established by scientific journals. As a consequence, the ideas presented in this book are largely limited to structures that can be assembled using components from the Commons of Ideas, whereas ideas built into structures composed by the subscribers to various journals can use a wider variety of components.

If ownership were always individual, then Joe and Bob would have to agree that only one of them can own either of X and Y (together with all its properties). Their agreement or failure to agree depends on the perceptions they control with respect to X and Y. If either of them wants exclusive use of the properties of X, then the other cannot use any property of X without setting up a conflict. X, however, may well be an atenex, as it almost surely is if X is material. In that case, one must enquire whether some properties of X are considered as being available as atenfels for both Joe and Bob.

If, however, Joe and Bob can agree on a trade for Bob to have some rights to X in exchange for giving Joe a sufficient quantity of Y, Joe ceases to control for Bob not to have access to X. One might say that for an "entrance fee" of Y, Bob has become a member of a "Club" consisting of people who can use X for a defined set of purposes. Depending on the terms of the agreement, Joe may still own X but Bob has the right to use it, or Joe and Bob may collectively own X, with each having the same rights in respect of using its properties as atenfels. If the agreement is for Bob to join Joe as a partner, the two of them having equal rights to X, then they also have to agree on how to decide whether and under what conditions to allow other people to "join the club".

There are many ways in which Bob may trade for access to the atenfels provided by X. Among them is subscription or rental, rather than joint ownership or sharing of a subset of the atenfels of the atenex that is X. In most forms of rental, Bob can use all the properties of X, but only for a pre-specified time unless he provides more of Y (e.g. money) to extend his partial rights to use X. But let us ignore these possibilities and look for now only at the case in which Joe extends equal rights to Bob so that they become equal owners of X in a partnership or membership club.

Maybe it would be better to talk not about the atenfels that Joe and Bob cannot keep for themselves, out of the indefinite number of atenfels that a material objects could supply, but to talk instead about the atenfels explicitly controlled collectively as a component of their ownership of X. For example, if X is a piece of land on which cattle can graze, as in the frequently cited example from Garrett Hardin's (1968) "Tragedy of the Commons", then what Joe and Bob might own could be such things as the right to exclude cattle not owned by one of them, the right to prevent other people from walking across X, or the right of others to disturb the plants growing on X. As we will discuss in Chapter IV.1, only social Collective Control enforces these ownership rights to exclusive use of those atenfels.

One of the rights of ownership is, as these examples suggest, the right to have exclusive use of defined atenfels of the thing owned. But now both Joe and Bob together own X, and if Joe wants to allow Sybil to use one of those atenfels, and Bob does not, they are in conflict. Continuing to use a meadow as the example of X, Sybil might want to walk across it to see the view from a good viewpoint in the meadow, but Bob does not like Sybil, and does not want her to have that pleasure.

Up to this point of the discussion, we have not considered how Joe and Bob (and Sybil) might resolve such a conflict. Ownership, however, being a perception collectively controlled by the wider society, one of the properties that society collectively controls might be a way of solving the problem. Joe originally had all the rights to the ownable properties of X, including the collectively controlled authority to control his perceptions of who was allowed to do what with X. He traded a share in that authority to Bob, creating a "club" whose members can use those properties of X as atenfels.

Now Sybil comes along and wants to join the Joe-Bob "Club X". Joe and Bob may agree that they would or would not like Sybil to belong to their Club, whether as a full member, a member with limited rights to the atenfels provided by X, a renter of X, or in some other way have access to X. If Sybil also agrees with them, there is no issue. They all control for the same change of Sybil's state from non-member to partial or full member of "Club X".

The three-member Giant Virtual Controller (GVC) that controls its perception of Sybil's membership status functions the same whether they all agree, all disagree, or are two against one in their controlled perceptions of Sybil's future membership status. This GVC uses another, which controls the procedure by which access to membership is given. This procedure, an example of a Club by-law, is a perception controlled by the GVC of which only the existing partners are members.

In England, and presumably other countries, when people were all nomadic hunter-gatherers or lived in villages surrounded by wilderness, all land would initially have been unowned and usable by the public. Later, powerful lords claimed ownership of vast tracts around their strongholds, and excluded most people from using the land in any way without the lord's permission.

After the Black Death of the14th century, much land became common land available for individual farmers, until the death of Queen Elizabeth I in 1603, after which (to quote Wikipedia, retrieved 2019.03.11): "*The **Inclosure Acts**[1] were a series of Acts of Parliament that empowered enclosure of open fields and common land in England and Wales, creating legal property rights to land that was previously held in common. Between 1604 and 1914, over 5,200 individual enclosure acts were passed, covering 6.8 million acres (2,800,000 ha; 28,000 km^2)*. Even now, many towns and villages have a "Village Green" or "the Commons", to which everyone has free access. The same, in England, is true of traditional walking paths, which are legally open to the public. It is to this kind of Commons that the concept of "The Tragedy of the Commons" has been applied. But we will look at several other kinds of Commons.

Since everywhere on the Earth people originally lived in small nomadic groups, one might ask how it comes about that anybody owns any land at all. Why would we all not work on the principle that our ancestors passed on to us the stewardship of the land as Commons to ensure that it remains in good productive condition for our descendants and theirs descendants to maintain the stewardship down through the ages? this question is often involved in discussions about the rights of indigenous peoples in Canada, since land ownership by individuals was unknown until the European immigrant invasion.

An approach to an answer must be sought in topics we address in Part 9 and Part 10, on collectively controlled Authority and political power. At this point, we simply suggest that it may well lead to reduction in conflict if one can live in a dwelling where we expect to be largely free of other people's control of perceptions to change the way we use our dwelling. The concept of land ownership might have come into being along with the idea of fixed settlements and agricultural plots that require maintenance over the years. Howsoever that might be, in "developed" societies, if is now the Commons rather than individual ownership that is sometimes thought to be the anomaly.

III.8.4 Types of Commons

Garrett Harding's paper "The Tragedy of the Commons" (Harding, 1968) spawned a half century of research that still continues. The journal "Science" of December 14, 2018 contained a special "Insight" section in which several authors offered their opinions on the current state of knowledge about the problem. Can PCT offer a different viewpoint on the issue after all this time? Perhaps it may.

The example usually used in discussions of the Tragedy of the Commons is of a pasture open to the public to graze their flocks. The grass grows at a certain rate determined largely by the weather and the soil fertility. Once the grass has been grazed, it is useless for further grazing until the grass has been regrown. If the totality of animals in all the flocks eat the grass at a slower rate than it can regrow, then every flock owner will be happy, and the natural increase of the flocks by the birth of new animals is likely to lead to a long-term balance between the rates of eating and growing grass because of the changes in new-born survival rates in times of plenty and of scarcity.

Now, in the Hardin example, Selwyn, a selfish owner, adds more animals to his flock from somewhere else. While the grass lasts, Selwyn get richer because he has more meat and milk to sell. Initially that does not affect the other owners, but the balance between the eating and growing rates no longer exists, the grass is quickly grazed out, most of the animals in everyone's flock starve. All, including Selwyn, become very much poorer than they would be had the grass been allowed to grow at least as fast as it was grazed.

Harding casts this in the context of the ever increasing overpopulation of the earth, using examples that most popular commentators on the subject do not mention, such as energy, air quality, and the availability of food. He might equally well have emphasized the resources that we mine from the Earth, for once they are gone, they are gone. Unlike mined resources, however, the grazing Commons will replenish itself if it is left alone for a while.

A Commons exists because a collectively controlled perception is that no individual or organization owns it or any part of it. There is, however, a modular structure to the concept of a Commons. For example, is a co-operatively owned grazing field a Commons or not? It is owned by the cooperative, and cannot be used for grazing by anyone who is not a member of the cooperative. On the other hand if the bylaws of the cooperative do not disallow it, the Commons can be used freely and without notice by anyone who is a member. The size of this cooperative might range anywhere from an entire nation that restricts who can enter it and take advantage of its various laws and customs to a partnership between to people who agree to allow each other to use some property owned in common, such as a joint bank account.

Whereas mined resources are depleted by exactly the amount of material that is taken out of the Earth, and the grazing Commons is an example of a resource that is depleted by overuse but will recover if it is given time, there is a third kind of Commons that is augmented by being used, and suffers from not being used. We call this a "creative Commons". Two examples might be the Commons of ideas or the Commons of Inventions.

We can therefore loosely describe three kinds of Commons, which we can label by their characteristic examples, mining, grazing, and creative, according to how the resource remaining available for public use changes over time as usage increases. These types differ primarily in the time course of the remaining resource supply as a function of its rate of being used (Figure III.9.2). Each curve represents a constant usage rate, which is unrealistic not least because that presumes the absence of feedback between the Resource Remaining and the usage rate. Nevertheless, these three types of Commons (four if you distinguish overused from underused grazing) do have characteristically different behaviours as a function of usage.

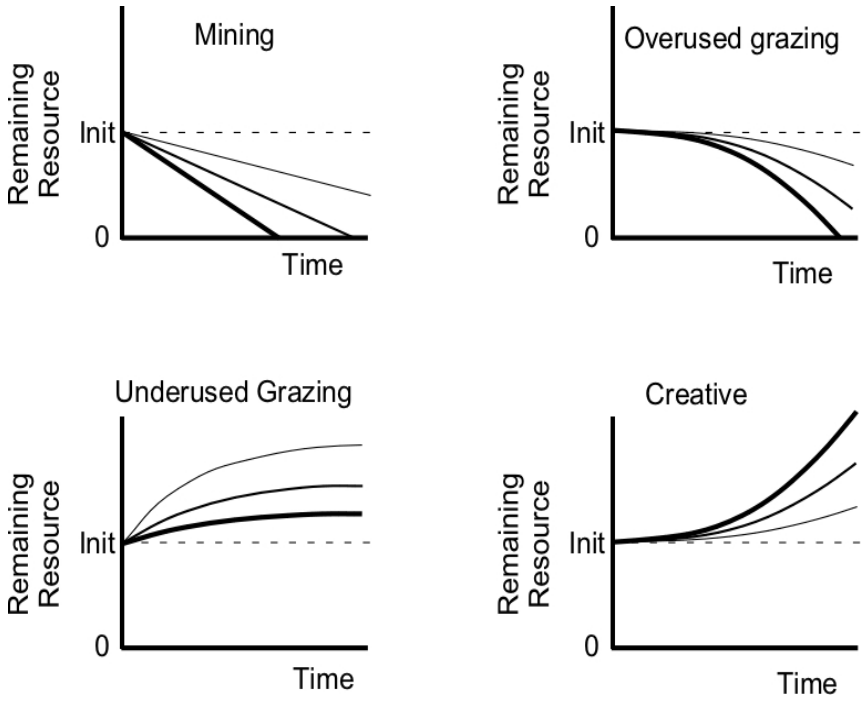


Figure III.9.2 Amount of resource remaining as a function of time for the different kinds of Commons as a function of their usage. Panels b and c both represent grazing Commons, the example most often used in popular discussion of the "Tragedy of the Commons", which is shown in Panel b. The thickness of a curve represents usage intensity, from low to high.

From the viewpoint of PCT, some of the ignored feedback paths seem obvious, while others may be found by analysis. For example, if a grazing Commons is the canonical grass meadow, any user can see how much is left, whereas if it is a fish stock, the only way to perceive the remaining stock is to note changes in the ease of catching fish as time goes by.

Both mining and overused grazing are forms of the Tragedy of the Commons. Overused grazing is the type usually mentioned in discussions, but mining may present the more serious long-term problem. When a load comes from the mine it is not replenished, as "they don't make it any more". To use mined materials in place of recycled materials is to live off our remaining capital rather than the income we get in the form of energy from the sun and nuclear processes. To use recycled material exclusively would change the type of Commons from mining into a grazing commons.

We will argue that "The Commons" is an important issue not only because of the Tragedy of the Commons problem Harding raised, but because the product derived from each type of Commons may be a catalyst for social productivity, which in turn feeds back into the usage rate of the Commons as a resource. How that affects the future availability of the Commons content as an atenfel depends on which type of Commons it is. For example, we will argue that the usage rate of a grazing Commons acts somewhat as does inflation in an economy. Too little use of an instance of this kind of Commons means that it is not contributing as much to the general welfare as it might, while overuse means that over time its ability to contribute declines dramatically.

One key point about all the types of Commons depicted in Figure III.9.2 is that not one of them is stable in the sense that there is some level of Remaining Resource toward which the Commons returns

after being disturbed by an increase or decrease in utilization. The nearest to this is the underused grazing Commons, the only one for which the Remaining Resource does not fall to zero or increase without limit. Even this is just a local equilibrium, since a sufficient increase in the utilization will lead to it being overused, after which it will decline to zero.

To create a stable Commons requires a negative feedback loop that corrects for over- or under-usage. Such a feedback loop implies that there exist some kind of regulatory structure, an Authority, that has the ability to measure the level of available resources in the Commons and the ability to act to change the usage level. If such a regulatory authority exists, it is hard to say that the Commons remains a Commons unless the regulatory authority is a construct collectively controlled by all those who have access to the resources supplied by the Commons.

III.8.5 The Commons: Energy and Structure

Of what use is a Commons to the Community or to an individual? That depends on what is being shared and what individual people as well as the various GVCs want. In a grazing Commons, what is being shared is a self-organized resource that depends on a through energy flow for its maintenance and (re)growth. In a mining Commons, what is shared is something of which the available quantity is not replenished in a time-scale of interest. In a creative Commons, the resource that is shared grows by virtue of being shared, and is not depleted by being used.

No matter the kind of Commons, what is shared is always structure in some form. Even in an actual mining operation the extracted product is part of the World's common supply of some element, compound, or crystal, which are structures of (at one level) protons, neutrons, and electrons that most users of mined material could not construct from raw hydrogen and helium, which are the dominant earliest natural source elements of all materials. It is true that most mines are owned, and only the owner has the right to extract and sell the product, but that is a detail of the management of the Commons, which we will discuss from the viewpoint of PCT below.

As Carl Sagan is reputed to have said: "We are all star stuff". Even the nuclear energy with which we can augment the immediate energy flow from the warmth of the sun to the cold of space comes radioactive elements created in the explosions of ancient supernovae. The oil and natural gas with which we construct an energy flow from the ground to the atmosphere was slowly constructed over millions of years from the stored energy of the sun. Over the long run, then, the through flow of energy that extracts the entropy to create and maintain the structures of life is from the sun and stars through the Earth and back to outer space.

In a mining Commons, the rate of replenishment is so low as to be negligible over the lifetime of an individual or even a culture. It works mainly on time-scales of the movements of continents or slower and almost always can be treated as zero for the purposes of this book. A living Commons such as a grazing Commons is different. The through energy flow is from the sun to outer space, with all the structures of and produced by life — much of it by perceptual control — as evidence of the Role of the energy flow in extracting entropy by self-organization from the systems through which it flows.

The solar-stellar energy flow to outer space may be the ultimate grazing Commons, but it is so universal as to be uninteresting in discussions about the social functioning of a Commons. Of more interest are lesser Commons that we might call "social" Commons. As is the case for so many kinds of structures we have considered in this book, these Commons can be subdivided into ever smaller and more specialized entities, down to, for example, the blood that flows in our bodies, supplied with the oxygen introduced in the lungs and depleted by the function of our cells. Our blood is a grazing Commons publicly available to all our cells in their quest for oxygen and other supplies.

As a grazing Commons, the main difference between the blood and a grassy meadow is that the cells cannot seek out places where the blood is richer in oxygen. They have to take what they are offered, unlike the cattle, who can go where the grass is greener (literally). What all varieties of Commons have in common is that they store energy in some form of structure (a "savings account") and release it to their various users.

From an information-uncertainty viewpoint, the grazing type of Commons can be seen as a structured, and therefore low entropy system that may be degraded by use. It is of low entropy because of the same self-organizing process as may have led to the first life (Chapter II.2 to Chapter II.5). This is true whether the resource supplied by the Commons is living, as is the grass on which the flock grazes, or is inert, like the concentrations of minerals that are called jewels or nuggets, or in a less concentrated form, ore.

Energy "leaks" from unmaintained structures as one facet of their increasing entropy (Section III.7.9), and this is as true of structures stored in the Commons as it is structure anywhere else, such as in the CEVs of temporarily uncontrolled perceptions. As McClelland pointed out, and as discussed in the last Chapter, with respect to the structured stabilities created and maintained in various other examples of Commons, that energy must be replaced in the maintenance of the structure.

Self-organization, export of entropy by way of a through energy flow, produces structure at a certain rate, whereas the "Makers" we discussed in the last Chapter take advantage of earlier production of material or abstract structure to create more complex structures to pass on to other users (Chapter III.6 Section III.7.8ff). The structure they extract subtracts directly from the total structure stored in the Commons, either by reducing total quantity of "stuff" that could be structured, or by removing structured "stuff" to allow it to be replaced by rawer source material.

This is not very different from the maintenance of structure powered by a continuous flow of francs in Section III.7.9, except that the living entities such as growing grasses that produce the structure (the "Makers") in the grazing Commons are not human and do not need to be paid money for their work (Figure III.8.8).

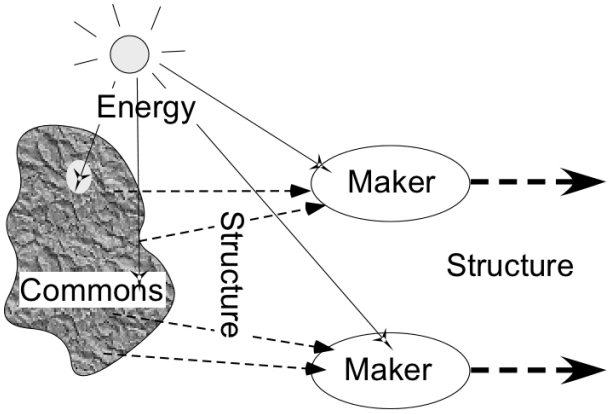


Figure III.8.8 Energy and Structure flow for a grazing Commons

Work, whether purely intellectual or physical, requires an energy flow, so the maintenance of all these stabilities requires a source of energy, which ultimately comes from the sun and older stars, but is channelled differently into and out of the different kinds of Commons, and is stored there until it is withdrawn either by lack of maintenance that allows entropic degradation or by being used in private perceptual control.

What is different about the Commons, as opposed to most of the environmental variables we talk about in the book, is that there is no direct feedback through the Commons from an individual user back to that individual, whether the user be a society of humans or a cell in the body. In a control loop, the user (the perception) is the maintainer (the output energy that opposes environmental influences that would cause the perception to depart from its reference). There is feedback, but only to the extent that the user is a member of a Community of users, all of whom are affected similarly by what any one of them does in the Commons.

Depletion of the quantity of structure created and stored in a grazing or a mining Commons for public use is a one-way process. The sun provides the entities in the Commons with the through flow of energy to create the structure, while a user uses that structure to perform perceptual control functions. The user does not create the structure gathered from the grazing Commons, but treats it as a simple resource that provides energy or atenfels.

It is quite possible for a herder who grazes his flock on a grassy Commons to pay something toward hiring a farmer to keep the grazing land in a highly productive condition. To do this would equally benefit every herder who might want to use the commons, and grazing by other flocks would greatly diminish the benefit to the herder who paid the farmer. The cost per animal for the philanthropic herder would be very high, so the herder probably would take this action only if the perception being controlled by it were not the welfare of the flock but the herder's self-image (self-self-image or other-self-image or both).

If the herder were not controlling a self-image with a reference value of having the property "philanthropic" she would not pay the whole cost of the farmer's work. Even if a herder were so philanthropic, controlling for the resulting other-self-image or self-self-image, there is only so much the farmer could do to enhance the regeneration rate of the grass. The enhanced regeneration rate of the Commons would support more or larger herds, and those would once again begin to deplete the resource in the same way. The so-called "Green Revolution" illustrates the same principle on a global scale.

Someone who pays the whole cost of maintenance is ordinarily the owner of whatever is being maintained, rather than a self-image-controlling philanthropist. If there is to be one specialized farmer for the Commons, the cost would ordinarily be shared among the herders, if they agree to do so. The collective control of the condition of the land then would be a variable controlled by a Giant Virtual Controller whose members included perceptions of the state of the land controlled by individual herders. If a number of herders do not agree to pay for a farmer to maintain the state of the Commons, the remainder may not be able to afford to pay him, with the result that the Commons continues its slow regeneration, and can sustain fewer herders than are currently using it up.

The problem of the grazing Commons can be simplified into one of energy supply. It takes energy to create structure (the structure of a blade of grass), and it takes energy to produce the structure (meat and milk) sold by the flock owners. The grass is an energy storage medium that, like the water in a leaky barrel, can be kept at a steady level only if the outflow equals the inflow.

The problem of the overuse of a grazing Commons is one of politics. Since we will be discussing the development of politics from a PCT viewpoint seriously starting in Chapter IV.1, we will defer further consideration of the problem of the grazing Commons until a more appropriate time.

III.8.6 Growth of the creative Commons of Ideas

The Commons of Ideas is the opposite of a grazing Commons. In Figure III.9.2 it is a "Creative Commons" in which, far from being depleted by being used, the Commons is augmented when it is used — when an idea accessible to a wide range of users is combined with another idea to create something

new and useful, and that new Idea is made publicly available. “Useful” might be in the form of an atenfel that becomes generally employed, or simply in the form of a new idea contributed to the Commons of Ideas.

We are, as you may have noticed, talking about autocatalytic or homeostatic creativity (Chapter II.2, Chapter II.3, and Chapter xII.14 above, and Chapter III.8 below). Before we go too far, we should consider what an Idea is, within PCT. An Idea is necessarily conscious, and therefore is not included within the reorganized perceptual control hierarchy. Nevertheless, an Idea has many of the characteristics of a perception, or perhaps of a conscious Elementary Control Unit (ECU).

An ECU incorporates both a perception of some state and a a perception of a means to influence that perception by using existing atenexes. The side effects of controlling the form and usage of the Idea may serve as a catalyst or a stage in an inventive homeostatic loop, either new or old. If it contains the conscious equivalent of an ECU in the reorganized hierarchy, the Idea is a “How to…” Idea, whereas if it does not, it is a “What is…” Idea. We do not need to distinguish these types when we talk of the Commons of Ideas, but it is useful to acknowledge the existence of the difference.

The “classical” grazing Commons of the “Tragedy” has a single depletable regenerating resource, though the concept is easily expanded to a situation in which there are multiple resources that could be used by a flock. For instance grass might grow in one field and alfalfa in another and a flock members might happily eat either. However it manifests, the grazing Commons has no direct connection from one resource to another other than the possibility that a user (the owner of a flock) might be able to substitute one for another. It cannot be described as a network, except through intermediate concepts such as the total nutritious value of all the plants available to the flocks. A Creative Commons, on the other hand, is intrinsically formed by a network of resources that can interact to augment the stock when used.

Any Commons benefits its users until the resource it provides is used up. A creative Commons benefits its users in perpetuity, because an Idea used remains available to be used again. Furthermore, its initial use might have added a novel Idea into the Common pool. Its users can be seen as “reactors” in the kind of homeostatic network described in Chapter II.2 and in Chapter II.3. Ideas in the Commons can be destroyed or altered, and can be lost by disuse, but so long as they continue to be at least somewhat available to some user, they always retain the possibility that they might be regenerated by being used.

The product of any one stage in the development of the network of Ideas is a new structural complex, a new Idea or a change in the structure of an existing Idea. The resources in the creative Commons of Ideas are mostly generated by the users who take advantage of them. They are structures created by control processes that use an information flow to reduce the entropy of some part of the Universe.

It may be valuable to compare from an informational viewpoint the development of a perceptual control hierarchy by reorganization with the evolution of a Commons of Ideas. As we pointed out in Chapter 9, information must be about something, and in control the information conveyed to the environment is about the reference value for the perception of the CEV. But that is a local view, both in time-scale and in the environmental context.

Considered more widely, as we did in Chapter II.5, reorganization has shaped the perceptual functions that produce the perceptions available to be controlled. The shapes that emerge and survive during reorganization produce perceptions that have tended to maintain the intrinsic variables of the individual within survival bounds at least long enough to allow many individuals to produce descendants. Nature has provided the structural information for lower level perceptual functions through the slow processes of evolution, but these are refined and higher-level complex perceptual functions are created by reorganization.

An Idea is like a perceptual function in that it "makes sense" of some pattern in the environment or that already exists in the Commons of Ideas. The structure embodied in an Idea is typically about other Ideas, just as the inputs to a perceptual function are perceptions created by lower-level perceptual functions. As with the control hierarchy itself, at its most basic level the network of Ideas contacts the environment. Sometimes we call that contact between the environment and the network of Ideas "Science".

When we are talking in the context of Science, what we call an Idea is more commonly called a hypothesis. A hypothesis describes data patterns that have been or may yet be observed, and is therefore subject to possible falsification if it describes some data pattern that could not be observed if the hypothesis is correct, and that pattern is actually observed. Few hypotheses are so precise, and when an "impossible" pattern is actually observed, someone usually manages to find a way to explain it that allows the hypothesis to be maintained, at least until a simpler hypothesis is proposed to explain the same data differently. A false Idea that remains available in the Commons of Ideas can be considered a form of pollution, or as noise that introduces uncertainty into the communication of information between the environment and the perceptual systems of the users of related patterns of Ideas.

Watanabe (1969) defined a measure of the credibility of a hypothesis given a particular dataset. The actual definition of this measure does not concern us. What does concern us in connection with the Commons of Ideas is that the credibilities of hypotheses will form into two divergent sets as data accumulates that all the competing hypotheses could describe. One set is of discredited hypotheses, the other of hypotheses that remain plausible. As the amount of mutually independent data increases, the separation between these two classes of hypotheses becomes clearer and less fuzzy.

Watanabe was taking the Analyst's viewpoint, and did not take account of the network of interconnections among hypotheses, which depend greatly on the perceptual functions that produce the "hypotheses" within a particular brain.

As we discussed in Chapter 10, all we can ever discover from observation and experimental probing of Real Reality is the set of ways that one of Wiener's White Boxes interacts with another White Box to mimic the way our observations and experimental probing shows Real Reality to function. We have constructed each White Box so that it emulates the functional behaviour of a corresponding Real World Black Box to within the level of precision allowed by the data used to check it. Each White Box corresponds to one of Watanabe's hypotheses, and to a perceptual function in the control hierarchy of the individual who perceives the corresponding aspect of the Perceptual World. Watanabe's measure of credibility refers to the likelihood that the functional relationship among perceptions or Perceptual World properties is as described by an Idea.

PCT asserts that since even identical twins do not receive the same sequence of inputs to their sensory inputs, their lifetime reorganization is likely to lead them to perceptual hierarchies that differ, if only marginally. Although the twins may usually agree about what they perceive in a given situation, they will not always do so.

For people who are genetically distinct, the probability of perceptual disagreement is greater. Accordingly, if two people disagree on the credibility of a hypothesis about the data they have perceived, it may be true that they are not using as data the same functions of observables. It may be difficult to determine which version of the data — the perceptions output by different perceptual functions operating on the same inputs — is more likely to be a credible hypothesis about the Real Reality that we can never know apart from approximations to the functions that relate its components and sub-components.

The consequence is that in the Commons of Ideas, the "truth" of a hypothesis is a Collectively controlled artifactual variable, not determined by Watanabe's criterion. Two different Collectives may

come to disagree on which of two hypotheses is more credible as an explanation of the available data when the data being used by the two collectives to test hypothesis credibility form two distinct networks of mutual support — two different perceptual hierarchies that define the perceptual control hierarchies in the Giant Virtual Controllers used by the two Collectives.

In Chapter III.5.we asked about the concept of "truth" itself, as distinct from perception or belief. When two different Collectives hold two different versions of the truth about the ways the data available to their members inter-relate, there may be no way to reconcile these versions satisfactorily. For example, all the data that are agreed to be factual might easily have been created in place a few milliseconds ago or 6000 years ago by an omnipotent deity. No conceivable new data could disconfirm either hypothesis or prove it more credible than a theory that the Universe was created some 13.5 billion years ago in a Big Bang that started from nothingness. Indeed, a naïve understanding of Ockham's Razor would see to favour one of the first two possibilities over the Big Bang theory[37].

We saw in Chapter 11 and Chapter 12 that autocatalytic and homeostatic processes are creative by their very nature. In Chapter 11 we discussed the production of autocatalytic loops in a "soup" of elemental components that are combined into complexes in different reactions, some of which may produce complex products that can serve as catalysts for other productive reactions. The twin Commons of Ideas and of Inventions are such "soups" in which the complex produced by one combination of ideas might act as a catalyst in a different reaction among ideas floating in the conceptual soup.

The so-called "soup" is thus better described as a medium that surrounds and contributes to a network, much as the biochemical "soup" of hormones and enzymes within a body surrounds and contributes to the functioning of the nervous system. Kauffman's developing autocatalytic networks are built directly out of just such a soup. As Kauffman (1995) pointed out, the more such a soup is used, the richer and more productive the network supported by the soup becomes. As we see next, and as we saw in a different "soup" in Chapter II.2, structures in the soup decay over time if they do not participate in at least one creative autocatalytic loop.

III.8.7 Depletion of the Commons of Ideas

Even a Creative Commons, such as the Commons of Ideas, is not immune to entropic decay, any more than is any other structure. Even though Figure III.9.2 shows a creative commons as having only growth curves, if the Ideas are not refreshed by being used, or at least accessed, they will decay away. We know very little, for instance of the ideas embodies in ancient Babylonian mathematics, or whether there existed schools of philosophy in ancient Uruk. If those Commons of Ideas ever existed, their Ideas may have been reinvented, but they were not kept current over the millennia in the way the philosophical ideas of Athenians 2500 years ago have been.

A cow can graze all over a field of grass in a grazing Commons, but an Idea in a Commons of Ideas cannot be found in the absence of an index or a link to another Idea. Just as in the elemental soup of Chapter II.2, a structure of Ideas that is not refreshed decays at some rate that depends on the strength with which the component Ideas of the structure both within and outside the Commons bond together, and is refreshed and strengthened by being accessed and used in the creation of new Ideas.

An Idea that is part of a network is likely to be accessed and possibly refreshed when a neighbouring Idea in the network is accessed and used. This is even more true if the Idea is part of an autocatalytic loop. If it is, it is self-refreshing, in that it promotes access to its neighbours around the loop, they promote access to their neighbours, and so on around the loop until the cycle refreshes the Idea initially

37. A Working Paper from 1972 in which I analyzed Ockham's Razor is annexed to this Chapter

accessed. The World Wide Web (the Web) is a medium, though not an amorphous "soup", for the Commons of Ideas, and one that allows sufficient data to support all kinds of studies.

Candia et al. (2019) studied the time-course of the rate of accessing different kinds of information available on the Web. In the five disparate fields they studied (citations of academic articles and patents, and the online attention received by songs, movies and biographies) the rate of access to these structures declined bi-exponentially over time, with an early "fast" exponential decline followed by a continuing "slow" one[38].

Candia et al. propose that the bi-exponential decline is the result of two separate processes acting together. They call these processes "communicative" and "cultural" memory loss. According to them, communicative memory is dynamic, new instances occurring when a new item is passed from one brain to others in the manner of a spreading contagion. This dies away as initially susceptible people become immune to reinfection or run short of places and reasons to cite the idea as a novelty. Cultural memory is more static, the structure in an infected brain degrading over time for lack of maintenance. Both form aspects of the Commons of Ideas.

Following the PCT line of argument that we have been using, the two modes of decay mentioned by Candia et al. make sense. An Idea is a conscious perception, and is thus amenable to conscious control. As a perception, it depends on the interplay or function of pre-existing Ideas, or, as explained in the Annex to this Chapter, on the prior understanding held by the perceiver. Kolmogorov information analysis, which depends on what the receiver of a message already knew and what was new to the receiver in the message, seems to be the best approach to understanding this development or creation of a new (to the perceiver) Idea.

When a new Idea is placed in the Commons of Ideas (made public) by its inventor, it has few access links within the Commons network that would make it likely to be accessed. Access by means whose currency is evanescent, such as notices of the tables of contents of journal issues, newspaper items, and so forth corresponds to the "communicative" mode of decay, whereas access to the public contents of those same journals correspond to their "cultural" mode. In either case, once the Idea has become a perceptual function in the person's brain, it supplies little or no information when it is accessed again.

The data used by Candia et al. are not ideas as such. They are accesses to ideas, but the principles would be the same. The Commons of Ideas "soupy network" consists of a continually changing mix of newly emerging ideas and old ideas that degrade in a bi-exponential fashion, always ready to be increased in concentration by being used, and becoming less and less accessible when ignored. In this, the "soup" is like a grazing land undergoing crop rotation differently in different parts of the field, allowing different kinds of animals to graze where the ideas are nourishing for them and letting less palatable idea crops to be invaded by weeds and allowed to dry out without watering.

The resources of this "soup" Commons become depleted also if non-consensual Ideas introduce noise. A non-consensual Idea may prove to a better description of Real Reality's functional relationships than the current commonly accepted truth, but it competes with the currently consensual Ideas whatever later happens to be the truth. It increases the uncertainty of a user about whatever the two ideas disagree on.

Non-consensual Ideas are analogous to the introduction of toxins into the biochemical "soup". Most such toxins are damaging to the organism, but some confer benefits as well. The same is true of novel

38. Taylor (1963) had found the same bi-exponential decay in a very different domain and time-scale, the rotary motion after-effect. Is it possible that an explanation functionally similar to the one proposed by Candia et al. (2019) might also account for this finding?

Ideas that conflict which generally accepted Ideas. They destroy or damage regions of the Commons of Ideas networks, and occasionally that damage benefits the larger Commons.

Fraud is a different kettle of fish. The introduction into the "soup" of complexes based on false data reduce the trust required for the building of complexes of Ideas from non-fraudulent components. Its productive homeostatic network can run down in another way, if the energy supply to the "reactors" (funding for scientific research and its transfer into technology) is insufficient to maintain the operation of the reactors (the work of research by the individual researchers).

For ideas, any loss is measured not in the structural form of the idea itself, but in the number of linkages to and copies of the idea that might be stored in a distributed fashion in print, in citations, and in the heads of those who might use it in the creation of new ideas. As we have said, one set of linkages among Ideas are those that incorporate ideas already current in the Commons into a new Idea just as other perceptual functions in the control hierarchy have as inputs lower-level (but not necessarily simpler) perceptions.

Ideas, however, are not necessarily linked hierarchically. One Idea can serve as a catalyst for the interactions among other Ideas as well as being a candidate component of another Idea, just as in our chemical soup (Chapter II.2) one complex may serve as a catalyst in a reaction involving quite other components. Eventually, in the chemical soup, it is statistically almost certain that self-sustaining homeostatic loops will form, in which each complex supports the relationship that creates the next complex around the loop. The same is true of Ideas. If there are enough of them of a wide enough variety in the Commons, it is almost inevitable that self-sustaining loops will form.

We have names for such loops: "scientific disciplines", "religious doctrines", "medical specialties" and so forth, not to mention "schools of thought" in which Ideas swarm together like schools of fish. When they have been established, it is difficult for a new Idea, even one that is to a non-participant in the loop a clear improvement over an Idea participating in the loop, to gain a foothold. As just one example, consider the vicious outright rejection experienced by Ignaz Semmelweis when he tried to promulgate his discovery that hand-washing by the attending physician greatly reduced maternal deaths. Here is s small extract from the Wikipedia article on him[39].

> *Semmelweis discovered that the incidence of puerperal fever (also known as "childbed fever") could be drastically cut by the use of hand disinfection in obstetrical clinics. Puerperal fever was common in mid-19th-century hospitals and often fatal. Semmelweis proposed the practice of washing hands with chlorinated lime solutions in 1847 while working in Vienna General Hospital's First Obstetrical Clinic, where doctors' wards had three times the mortality of midwives' wards. He published a book of his findings in Etiology, Concept and Prophylaxis of Childbed Fever.*
>
> *Despite various publications of results where hand washing reduced mortality to below 1%, Semmelweis's observations conflicted with the established scientific and medical opinions of the time and his ideas were rejected by the medical community.*

Other examples might include Galileo's trial for heresy for espousing the Copernican heliocentric theory of the organization of the Sun and planets, the destruction of the Library of Alexandria and the murder of the great female mathematician Hypatia by a Christian mob in 415 C.E., and currently in the

39. Wikipedia article "Ignaz Semmelweiss" retrieved 2020.10.15.

USA the rejection of climate science as part of a total world-view espoused by the followers of President Trump.

In Chapter 9 we described Lateral Inhibition among control loops, and showed some of its influences in control, not least among which was a polarization in which only one of two perceptual interpretations of data, was accepted. In that context, the phenomenon was called “category perception”, in which some complex of property values could belong to only one of two possible categories.

If an Idea forms part of a stable complex, an Idea that might contradict any member of that complex is more strongly rejected than it might be in the absence of the self-sustaining module, loop, or network cluster. If there are two complete homeostatic loops in which some ideas in one loop contradict some ideas in the other, those loops are more likely to draw apart conceptually than to coalesce into a loop that incorporates the stronger points of both. As a professor in a class I took as a graduate student said a long time ago (I paraphrase): “If two schools of thought each say the other is wrong, they are probably both right.”

Here we have an equivalent lateral repelling interaction between entire homeostatic loops of Ideas that reject each other whether the loops occur across individuals within the Commons of Ideas or between a Collective homeostatic loop and a loop of Ideas within an individual. As we discussed in Chapter II.2, two homeostatic loops in a soup (chemical in Chapter II.2) have the possibility of creating a conjoint stable loop that contains some catalytic processes from each of the original loops, but this becomes less likely to happen if the older loops repel each other.

Yet the Commons soup probably contains other Ideas that are independent of the antagonistic stable “world view” loops, and these “free floating” Ideas might well form growing clusters that could become stable by incorporating some Ideas from the existing loops, possibly breaking one or both of those loops in the process.

We will consider the interactions of political parties starting in Chapter IV.1, but it is worth using them as an example here, to make the concept of interacting stable loops more concrete. Political parties usually are based around homeostatic loops of mutually self-supporting Ideas that together constitute a stable world view. The Commons within which these parties operate consists of the possible affiliations of the members of the electorate.

Party affiliations are, for most people, all-or-none, especially if there are only two major parties. If stable world views are stable because they form homeostatic loops or networks, the foregoing analysis suggests that the platforms of different parties will tend to diverge increasingly as time passes. We will discuss the political problem associated with the Commons of Ideas in the second half of Chapter IV.1.

Chapter III.9 The Trade Motif

III.9.1 Transfer of Ownership

Let us say that Carol owns a Chinese bowl that her friend Yvonne would like to have. Since Carol and Yvonne are friends and honest people, we assume that Yvonne will not attempt to steal the bowl. What does Yvonne actually control for? She can see the bowl whenever she wants, by visiting Carol. She might be able to see it more conveniently if it was in her own house rather than Carol's, and she might be controlling a perception of how convenient it is to see the bowl. Or she might imagine that the arrangement of her own Chinese porcelain collection would be nearer her reference level for it if the bowl were to be included.

Let us instead assume that what Yvonne is controlling for is a perception that supports both those possibilities, that the collectively controlled relationship of ownership between Carol and the bowl should be broken and the ownership relationship should be collectively established between herself and the bowl. In simpler words, Yvonne simply wants to perceive and to have others perceive (which are two quite different things), that she is the owner of the bowl.

Carol also wants to perceive and to have others perceive that she owns the bowl. Since at the start of this example she is generally perceived to own the bowl, there is no error in her controlled perceptions with regard to the bowl ownership. Those perceptions are not disturbed when Yvonne says she is interested in owning the bowl, so what perceptions might Carol be controlling that would be disturbed by Yvonne's statement? They must have something to do with an imagined state of the world in which Yvonne owns the bowl and Carol doesn't, since the actual state of the world is unaffected by anything Yvonne says — except possibly by something like "I've seen a judge and she says that the bowl is actually mine", which would disturb Carol's perception that others perceive her to be the owner of the bowl.

We are dealing with a Barter and Trade (or Buy and Sell) protocol (Section II.5.5). When Yvonne initiates the protocol by asking whether Carol would swap the bowl for something Yvonne has (perhaps money) both of them have a perception of the relative worths (to themselves, of course) of the two objects. In Barter and Trade, conflict between the parties ceases only when both perceive the worth of what they will give to be less than the worth of what they will get (though the internal conflict remains in each party, since neither can have both the bowl and whatever Yvonne offers).

Perhaps for Carol, the bowl is the only remaining memento of a much loved grandmother, and she values it more than anything Yvonne could offer, even if Yvonne were a billionaire. In Carol's perception, the bowl has an imaginary tag "Not For Sale". In that case, Yvonne will not get the bowl by purchase or barter, and if she really wants the bowl (perhaps it would complete a priceless collection) she will need to try some other way to get it.

Most of those ways are of dubious legality, in that they do not allow for *collective* control of the ownership to change state from "Carol's" to "Yvonne's". Both Carol and the Grand Virtual Controller would still perceive the bowl as "Carol's", even though Yvonne might perceive it as "Yvonne's" for all practical purposes. If Yvonne was controlling for perceiving that the collective perceived the bowl as hers, she would need to act legally, perhaps by appealing to an authority such as a court.

It is not necessary to detail the stages by which Carol and Yvonne arrive at a conflict-free state, a state in which Carol values what she will get from Yvonne more highly than what she will give, and vice-versa. When they arrive at this state, Carol hands the bowl to Yvonne and Yvonne gives Carol the agreed price

(money or some barter object or service). Both Carol and Yvonne have increased their own worth, or at least their perception of it.

If this transaction result is not perceived by others, the collective continues to control the "bowl ownership" perception as "Carol's". Yvonne and Carol must act together to change that collective perception. The Authority by which one has the rights of ownership of the bowl also gives the owner the right to transfer the ownership to someone else.

One of the basic tenets of PCT is that actions are the result of error in a controlled perception, so if Carol and Yvonne both perceive Yvonne to be the new owner of the bowl and they both have that as the reference value for the perception, why would they now act further? They act because they control a perception that for both of them differs from its reference value. Both perceive that the community Giant Virtual Controller currently controls for Carol to be the owner of the bowl, and they both have a reference value that the public GVC should control for perceiving Yvonne to be the owner.

Yvonne and Carol must together perform some collectively controlled ritual to allow the community Giant Virtual Controller to perceive the change of ownership, just as in Section II.11.9 we argued that the ritual of marriage is performed only to change the World Model of the same Giant Virtual Controller by changing the reference values of its member individuals for their perceptions of the relationship between the pair.

If Carol simply hands Yvonne the bowl, the GVC would still control for perceiving Carol to be the owner. If Yvonne were to go around showing the bowl off and saying "It's *my* bowl", thereby conducting a "Test for the Controlled Variable" on the GVC, any member of the collective would be liable to say "No it isn't. It's Carol's", thus demonstrating that at least one member of the GVC was controlling a perception of the bowl's ownership and had the wrong reference value for it (wrong in Yvonne's mind).

When we discussed protocols for the passage of information, we mentioned that new information could change perceptions at almost any level of the hierarchy, and therefore could influence reference values at many levels because of changed output as the controller of the changed perception acts to correct the resulting error. If this is true of individuals, then it is true of the Giant Virtual Controllers of which those individuals are members. However, not all individuals have the same perceptions of the world, and nor do they necessarily all control those perceptions for which they do hold the same perception.

Even though a Giant Virtual Controller may strongly control a perception of the ownership of the bowl with a reference value of "Carol's" some of its individual members may not. Suppose Yvonne had stolen the bowl, and tells Zenia it is now hers. Zenia might believe her. The deceived Zenia now controls the ownership relation with a reference "Yvonne's", opposing the Giant Virtual Controller. Quite possibly, however, Zenia is not so easily deceived, and her control action may be to ask Yvonne to justify her claim, because it conflicts with the way Zenia perceives the world.

But in our example Yvonne did not steal Carol's bowl. They agreed a transfer of ownership so that both of them now perceive Yvonne to be the owner. How can Zenia perceive that Yvonne did not steal the bowl? Yvonne's claim is the same whether or not she stole it, so the perception of ownership must have another element. One possibility is that Carol also tells Zenia that Yvonne is the owner.

But now suppose Carol is deceptive, and claims that she still is the owner, despite actually having traded the bowl to Yvonne. Yvonne needs something else that will allow not only Zenia, but also the other members of the Giant Virtual Controller, to perceive that the trade happened. In everyday practice, we call that something a receipt. The generation of the receipt in some publicly verifiable form is the ritual that they need to perform.

Of course, as a means of controlling a perception that the Giant Virtual Controller perceives Yvonne as the owner, Yvonne could easily fake a document that says “Carol gave this bowl to Yvonne in exchange for three blue beads”. Even if it were true, nothing about it says that Carol agreed that it was true. The receipt needs to have some indication that Carol agreed with it. A signature has long been conventional, but may soon be superseded by some form of electronic identification.

We need not go that far, because we are really talking about trust. If Carol and Yvonne both attest that Yvonne is now the owner, the Giant Virtual Controller will begin to control the bowl ownership perception with that new reference value. Only if they do not agree does the Controller have a problem.

Solomon is said to have solved the problem of disagreement about ownership when two women claimed the same baby, by proposing that the baby be cut in half and each claimant would get half. The true mother had a much stronger controlled perception of a happy, whole, baby than did the other, so she conceded, whereupon Solomon perceived that she was the true mother.

The Giant Virtual Controller probably cannot use Solomon’s technique when the claimants disagree about ownership of the bowl, and might itself split into two separate Giant Virtual Controllers we call “factions”, one with a reference that it is Yvonne’s bowl, the other that it is Carol’s. Wars have been initiated this way, but the Giant Virtual Controller might instead act coherently and seek more information that would enable it to develop a reference value most likely to be compatible with what actually happened between Carol and Yvonne.

It might use a different well-defined ritual. An Authority we call a “judge” or an arbitration panel would decide, and the Giant Virtual Controller would set its relevant reference value according to its perception of the decision of the Authority, regardless of how Carol and Yvonne perceived the world. The “world” would perceive either Carol or Yvonne to be the — now we can use the word — authorized, owner.

III.9.2 Trade and the Evolution of Money[40]

In much of the rest of this Chapter, I use individuals in a small community as a metaphor for the historical development from barter to money. I arrive at the conclusion that money has nothing to do with tangible objects such as banknotes, coins, cowrie shells, or gold bars, but is an abstraction similar to language or style. Nor does it directly map onto Worth or Value, which we discuss in the next Section.

40. Much of rest of this Chapter is based on or copied directly from a presentation I made to the 2019 IAPCT Annual Conference, Manchester, UK.

Figure q29.1 Are these money? Were they ever? No, they are not and were not. They are or were media for communicating money from one owner to another.

Before there was money, trade was conducted by barter between people with different skills and specialties. I take a quasi-historical approach to suggest why money, once it was invented, rapidly superseded barter as the preferred method of trade. Eventually, I will reach the conclusion that Money is not tangible. It is a language in which the collectively controlled values of the *work* and *energy* expended by people in constructing and maintaining various goods and performing different services can be transmitted through the medium of trade. By "energy" here, I mean energy as it is understood by a physicist, to be measured in ergs and joules.

The reader must always be aware that my parable is a Just So Story, in that historically events ma have developed this way, but it is more likely that they didn't. It is, nevertheless, a story about how a PCT view of one stage of history could have led to what I suggest might have come next. I think it is plausible, despite being offered without archaeological evidence.

III.9.3 Basic Concepts

As we have mentioned several times before, a motif is a structure that recurs frequently among a complex of many equally complex possible structures, most of which occur infrequently or not at all. Informationally, a motif is a redundant structure, in that its label, in this case "trade" describes the structure almost completely. What remains to be determined are parameter values, not structural form. A

PCT motif is built from interacting control loops as molecules are built from atoms. Examples of PCT motifs we have already met are conflict, the protocol and the control hierarchy. In the next few subsections, I will describe the "trade" motif and use it to illustrate a PCT view of money.

We described "Worth" as early as Chapter 6, but it is probably valuable to put it into context, as a technical term: The pleasure you get from the things you have and from your perceived ability to control the perceptions you want to be able to control. "Worth" has no extrinsic properties, but is entirely a property of one's self-self-image that can be perceived and controlled. Trade is based on one's perception of one's own worth. One's Worth is personal, relative, and variable over time. Nobody can perceive another person's "worth". The "Trade" motif represents the control of their individual perceived "Worths" by two trading partners.

Value is not the same as Worth. If Worth is a perceptual variable with a value X, the Value of an event is ΔX. Like Worth, Value is a perception without an environmental referent. If your Worth is your perceived pleasure in what you have and can do, the Value to you of something is your perception of how greatly it might enhance that pleasure if you were to acquire it or diminish them if you were to lose it. Your self-perceived Worth changes according to the Values that contribute to it.

As an example, if you want to cross a brook dry-shod and there is no bridge, your ability to control the perceptions of foot wetness (reference: dry) and of being in a desired location (reference: on the other side) is very poor. If you then see a plank on your side of the brook, and imagine placing it across the brook to walk dry-shod over it, you perceive the plank as having positive "value" to you because it gives you a means to control a perception you could not have controlled earlier.

We can treat the concept of Worth in the same way as we updated Ockham's Razor (Working Paper W1). Okham's Razor originally was quoted as saying that if two theories equally well accounted for the same observations, the simpler should be preferred. This formulation has an intrinsic problem, that "simpler" is a perception in an individual, and what is simple to one individual may not be simple at all to another. It depends on what each knew before attempting to explain the observations using the two theories.

Beyond this interpersonal difference in identifying which of the two theories is simpler in explaining a defined set of observations, if one theory explains an apparently different set of observations that the other does not, the extended range of explanation may be enough to offset a reduction in simplicity (Working Paper W1 specifies mathematically when this may occur). Finally, if two equally simple theories have the same range of explanation, but one explains more precisely than the other, the more precise should be preferred. Working Paper W1 puts this three-way trading relationship mathematically, but that is of no particular interest here. What is of interest is that we can treat Value and Worth the same way.

Both words "Value" and "Worth" are often treated as applying to quantities of money, but from a PCT point of view, that treatment is simply a formula that applies to the environmental correlates of some perceptions. This view is encapsulated in the question "What's it worth to you?". The answer can't be a certain number of dollars unless that number represents what you are willing to trade for it in money. That number of dollars is the most that has less value to you than "it" does. How many that might be depends strongly on what proportion of your available dollars you would lose by accepting "it" in trade. A dollar for someone eking out an existence on minimum wage is far more valuable than it is to a billionaire who likes to flaunt his wealth by pretending to smoke rolled-up hundred dollar bills.

Money has a Value to someone only as a differential, how much it changes the person's total ability to control their perceptions, or in other words how much it changes the person's Worth. Taking our cue from Ockham's Razor, Worth corresponds to what you know already, and Value to how much you gain by

accepting a theory. Both Value and theory acceptance are differentials. According to Working Paper W1, simplicity, range, and precision of application determine which of two theories is preferred. We should anticipate corresponding dimensions in determining the Value of something one might acquire in Trade.

III.9.4 The Trade Motif

Trade is a way of controlling your worth. Another person may have something you would value, such as a skill they might be able to teach you. You may have something of some value to the other, but of less value to you than what the other can offer you. You may trade what the other has or can do for what you have or can do, both of you losing a little value while gaining a greater value than is lost. Trade is one of many ways of controlling your worth. Normal reorganization increases one's worth by improving one's ability to control perceptual variables, and by increasing the repertoire of perceptions available to be controlled.

To make this concept more concrete, here is an example. Tam the Trimmer can cut hair. Tam wants a steak for dinner. Bud the Butcher can cut many steaks. Bud wants a haircut. To Tam, a steak received is worth more than a haircut given, while to Bud a haircut received is worth more than a steak given. Tam and Bud may be able to come to an agreement to trade. Tam agrees to cut Bud's hair if Bud gives her a steak. If Bud agrees, this is a "fair trade" (one in which both parties feel they would gain more value than they would lose by executing the trade).

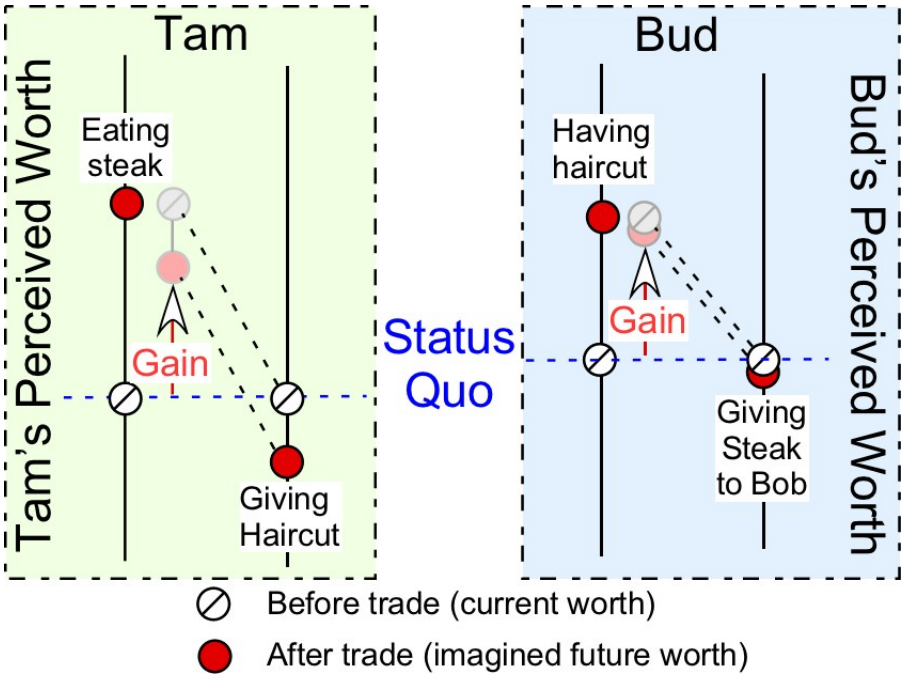


Figure q29.2 Potential values to Tam and Bud of trading Bud's steak for Tam's haircutting work. Note: "Gain" here is gain of worth, not the loop gain of a control loop.

Bud could cut a steak, and Tam could cut Bud's hair. But would they? Both control conflicting perceptions of having the steak, and (Tam) of being at leisure, or (Bud) of having his hair cut. Since neither can act to bring error to zero in both perceptions, the conflict motif is built into the trade motif. Perhaps Bud doesn't even want to have his hair cut because he is trying to grow it long for an amateur acting job he agreed to try (Figure q29.3).

As part of the PCT structure of this motif, we have to note that trade cannot be done without the use of protocols through which each party to a possible trade lets the other know what they would like and what they are willing to do. Tam has to let Bud know that he likes steak, and Bud must let Tam know that he wants a haircut.

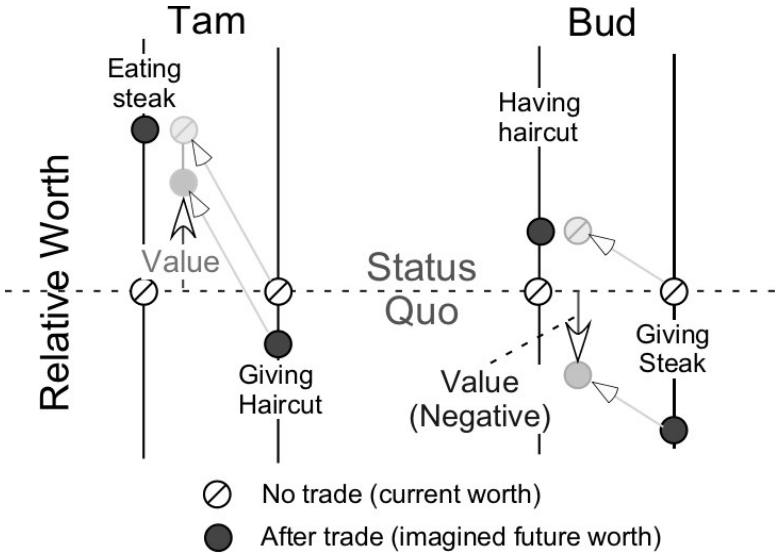


Figure q29.3 No trade. Bud won't agree to trade because he doesn't even want a haircut. Tam will not get a steak to eat.

More realistically, the suggested trade won't happen for a different reason, that Bud perceives that losing a steak would cost him more value than he would gain by having just one haircut. Tam must offer him something extra.

She offers him three haircuts, but Bud perceives that once he has had a haircut, two more right then would have no value to him. However, he expects he will want another quite soon. Bud accepts Tam's promise of two extra haircuts to be performed later, but in case one or other of them forgets that the promise was made, Bud asks Tam to put the promise on paper. We know such a piece of paper as an IOU. Tam writes and signs two "haircut IOUs" on paper. Her IOUs do not specify that the two haircuts have to be given to Bud, so Bud could possibly give one or both to someone else,whose hair Tam would be obliged to cut.

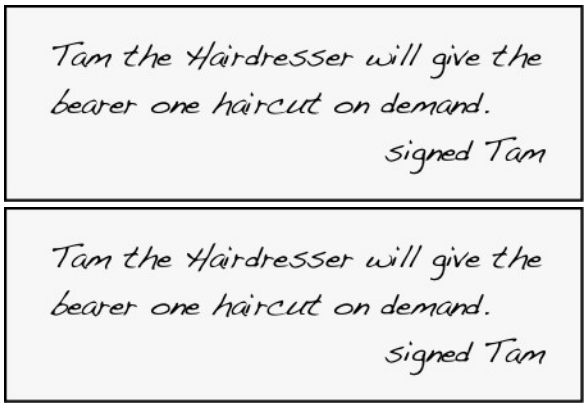


Figure q29.4 Tam's IOUs, which could be used by anyone. Are they money?

In Figure q29.2 and Figure q29.3 both Tam and Bud are shown as having precise estimates of the imagined value to them of making the trade, but this is unrealistic. Tam doesn't know how good the steak will be, and Bud doesn't know how much benefit his haircut will be in his daily life. For both of them, we must accept that there is a range of uncertainty about the imagined value of making the trade (Figure q29.5).

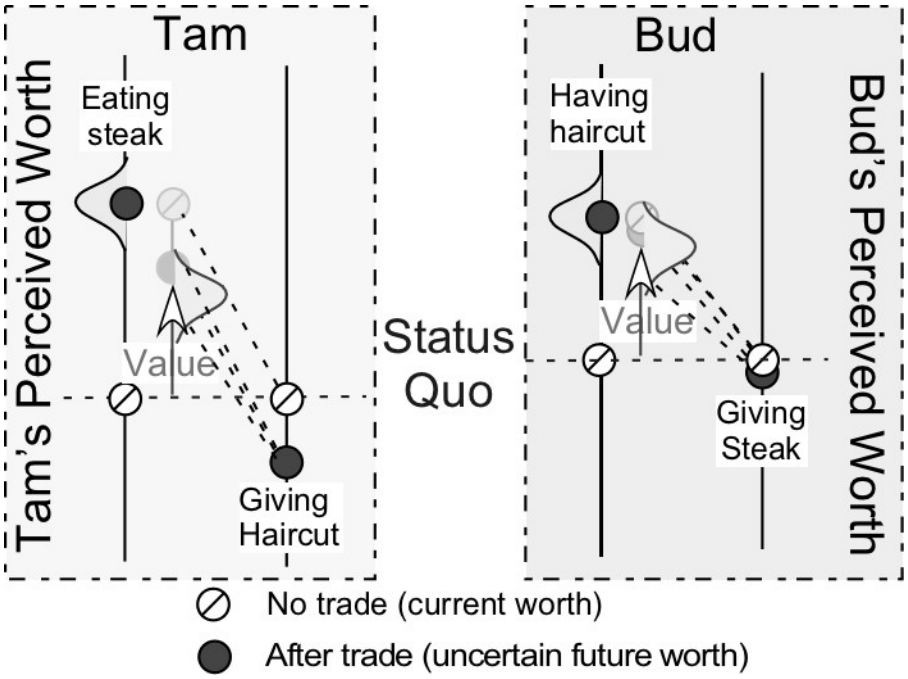


Figure q29.5 Both Bud and Tam are uncertain about how much their worth will change if they make the trade, the value to them of making the trade. Accordingly, they are likely to make allowances for the uncertainty, and ask for more while giving less than their current best guesses as to the value to them of what they would give and get.

You probably cannot perceive your own total worth very accurately, but you can perceive which of two options probably has more value to you. When there is uncertainty, there is risk of being wrong. Uncertainty reduces the trade value of any offer. Tam and Bud allow for error in their estimates, and reduce their risk by reducing the perceived values of what they are being offered relative to the uncertain value of what they are giving. To meet the conditions for fairness, the parties to a trade must allow for risk in the uncertainty they have about the values of what they might trade.

If he completes the trade of steak for three haircuts, Bud has two of Tam's IOUs. What might he do with them? IOUs are as tradable as are goods and services, so he might keep them and use them to get later haircuts, but also he might trade them with someone else who perceives them to be of higher value than what they would offer Bud, an offer that Bud perceives to be of higher value than the haircut IOUs.

Having seen Tam's trick substituting IOUs for actual haircuts, Bud imagines that he can also offer tradable IOUs, these good for steaks or other cuts of meat he would be able to provide, when he wants

something of more value to both him and a possible trading partner than one steak. Perhaps he wants someone to build him a cold-storage locker so that his meat will stay good longer. He could offer 100 steaks, but 98 of them might go bad before the builder could get around to eating them. But a steak and 99 IOUs for another steak is a different matter. Those IOUs will not go bad so long as Bud remains in business. Whoever has one would expect to be able to get a nice fresh steak for that day's dinner.

III.9.5 Tradeable IOUs

Soon more and more people realize they can offer promises (IOUs) when they don't have on hand what they need in order to make a fair trade (Figure q29.6).

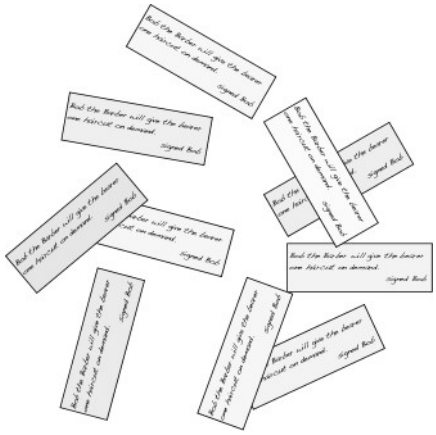


Figure III.7.6 Many different kinds of IOU issued by different people lead to confusion. Which can be trusted? Which are worth more than which to Bob, to Jill, to some random person at this moment?

But there's a problem when so many different kinds of IOUs are in circulation. Maybe the issuer is trustworthy and will deliver on request, but maybe not. How is a person who might trade for one but doesn't know the issuer to know whether the IOU will be properly redeemed when the time comes to want Tam's haircut, Bud's steak, or whatever is promised on its face? How does a person who wants a specific kind of IOU find someone who has one and is willing to trade for something the person has?

Like all uncertainty, uncertainty about the issuer reduces the value of an IOU in any trade. If there are many different kinds, most are nearly worthless unless the issuer is well-known to be honest, and even then they may not be worth much to most people if what the IOU offers is rarely wanted. Since every fair trade increases the worth of each party, the total amount of trading across the community will decline toward the baseline imposed by the possibility of pure barter trade without IOUs.

To find a suitable exchange rate between haircut IOUs and steak IOUs that is perceptible in the external environment is different from Tam and Bud coming one day to an agreement to trade three haircuts for one steak. There are other barbers and other butchers, and other times as well. Over time, there will be lots of different agreements between barbers and butchers, sometimes agreeing to trade two haircuts for a big steak, sometimes agreeing to trade only three future haircut IOUs for a small steak. The steak-haircut exchange rate might vary over a wide range of ratios, but if anyone has been keeping a record of completed trades, the average ratio will slowly approach some steady or nearly steady value.

Butchers and barbers are not the only people involved in repeated trades of one kind of thing for another. Tom and Bud both like bread, and if they want any, must barter with Bert the baker for a mutually acceptable amount of bread in exchange for steak or haircuts. Just as with steak and haircuts, there will be many occasions on which haircuts or steak are bartered for bread by different butchers, bakers, and haircutters, and the ratios between bread and haircuts or bread and steak will vary widely. And again, over time, the averages of these ratios will also tend to converge to stable values. So, as a consequence will the ratios of the ratios. The ratios form a network among themselves as well as between IOUs and what they promise. It all becomes more complicated than most people want to compute for themselves, and thus introduces extra uncertainty into both sides of every trade.

Into this mess may step someone new, who we might call "Financier Frank". Frank may offer a new kind of service, *matchmaker*. If a client is looking for a particular kind of specialized IOU, Frank will trade his work in finding one among the flood in circulation in exchange for a fee to be paid by the client in work, a product, or an IOU.

If the client has nothing available for barter small enough to make a fair trade for Frank's small fee, Frank adds some new IOUs of his own that he calls "francs", so that the client gains enough value for a fair trade. Frank's francs carry a promise that he will accept enough of them to make a fair trade for any IOU of the seeker's choice. Frank can ease fair trade for an arbitrary IOU by writing IOUs that say "Two and a half francs" or "a quarter franc". Writers of specialist IOUs for products or services cannot do this. But we now come to a problem. How much value should a client expect for the use of Frank's services that warrant accepting one franc as a fair trade? We will address this problem very shortly.

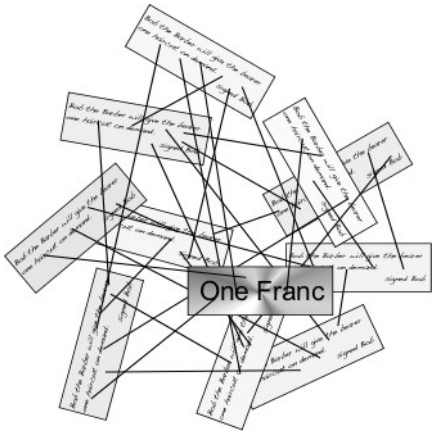


Figure III.7.7 The new kind of IOU promises no particular goods or physical services, but is added into the network of circulating IOUs nevertheless. It offers a search service, finding whatever specialized IOU someone wants in exchange for a kind that the client has.

After exchanging an specialized IOU for whatever goods or services it offers, the IOU holder is left with one IOU less to use. After exchanging one of those IOUs for one of Frank's new IOUs, the effective worth of the collection of IOUs held by the client has increased, since the client now has an IOU for something wanted in place of an IOU for something not wanted at present. Frank also has added worth, as he now holds an IOU he could expect to be able to trade to another client without having to use the work/energy needed to search for one held by some unknown person.

The first time Frank offers a franc for his matchmaking service, he has to bargain with the client about what his service is worth to that client at that moment. What IOUs does the client have or could create that both client and Frank would agree is a fair trade for Frank's service? The agreement defines the value of a franc to the client at that moment, within some bounds that define the range of neighbouring values both would agree to be fair.

Next time a client asks for Frank's matchmaking service, Frank can say "Last client paid this much for my work, and that is what one franc is worth." But this new client may think the relatively easy job he is now asking Frank to perform isn't worth that much to him, and Frank may need to bargain again, determining another possible value for a franc. After many such bargaining sessions, Frank has a good idea of how much work he should be prepared to do if offered one of his francs as an IOU rather than another specialized one. The work needed for each IOU search varies, and so Frank creates fractional and multi-franc IOUs (Figure III.7.8).

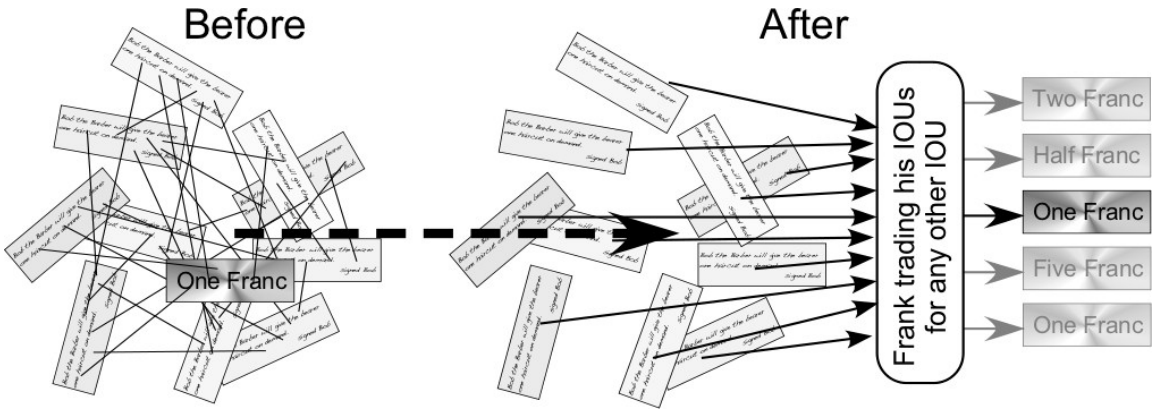


Figure III.7.8 After Frank has conducted many bargaining sessions, he begins to refine the value of a franc in terms of the work he must do to find a match. That work in turn begins to refine the expected value to the average client of each type of specialized IOU.

After having traded his work for N different kinds of IOU, Frank will get data points for the fair trade values of a franc compared to those kinds of IOU. He can use these N values to generate ratios of values for the N(N-1) pairs of available kinds of IOU ("Before" in Figure III.7.8). The averages he can compute are $\sqrt{2}N$ times less uncertain than the ratios that individuals can make from direct trading between specialist types of IOU. He can fix the price of a franc in terms of each of the other kinds of IOU, and can trade only in terms of these fixed values, rather than bargaining each time someone asks for his matchmaking service.

Tom and Bud, and all the others who traded haircuts for steaks, established an average exchange rate for such trades that usually increases the total worth of each party. The same is true for trades of haircuts for francs, and of steaks for francs. If these averages are consistent, the ratio between the franc to haircut rate and the franc to steak rate should be the same as the bartering exchange rate between haircut and steak. If a steak is on average valued at 2.5 haircuts in a barter economy, and a haircut IOU can be exchanged for one franc, then 2.5 francs should be a fair trade for a steak IOU (ignoring Frank's fee).

Every trade has its own uncertainty about the relation between the perceived worth of what a trader has and the imagined worth of what would be received. The long-term values of the traded entities relative to each other depend on "the same" trades, such as steaks for haircuts, being executed many times. With N different kinds of entity that might be traded, there are N(N-1) kinds of "same trade", but if all trades are restricted to having francs on one side of the trade, only (N-1) "same" kinds of trade are

possible. The averages have, on average, N times as many instances of a kind of trade as they do if each trade is direct barter of one kind of entity for another. The range of uncertainty is reduced by the substantial factor of √N.

At this point Frank could publish a price-list for what he would pay in francs and fractional francs for each type of IOU and what a client would need to pay him to get that kind of IOU. The average difference pays his matchmaking fee, rather than Frank needing to charge it on each occasion, though he may do so if he wants. He can in this way buy and sell IOUs that he has in stock, rather than having to make a match every time a client wants a particular kind of IOU (Figure III.7.9). The franc has a fairly stable public value separate from the value it might have to an individual at a particular moment.

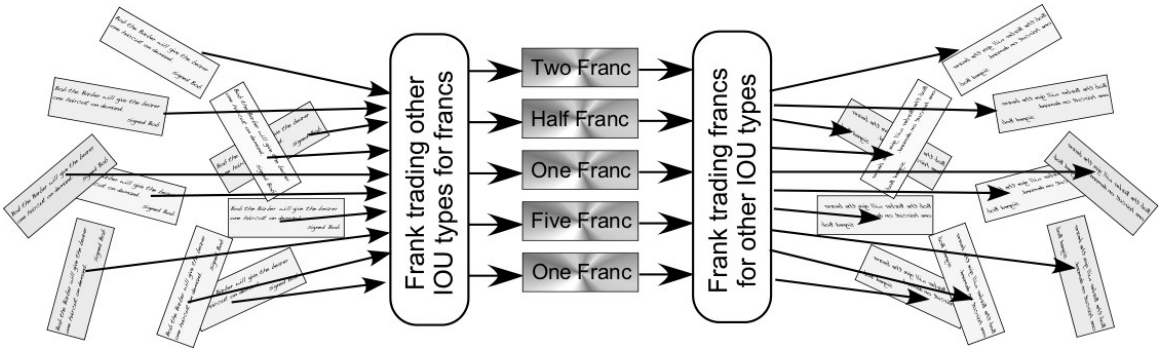


Figure III.7.9 Once the franc has a public value stabilized by the stochastic collective control of many transactions with Frank

The stability of the public value of a franc is a collective side effect of many individual controllers controlling their worth perceptions in trades for francs or other IOUs. Even though it is a side-effect, it is nevertheless an example of Stochastic Collective Control (Chapter xII.13) in that the mechanism that achieves stability is the same, but with no "target" for the stable value that results. The collective side-effect approach to stability is characteristic of many public "norms" that have evolved over time rather than being legislated.

As McClelland noted in the extended quote in the Introduction to Chapter II.4:

> *The kinds of activities described as work in everyday language are activities that create stable feedback paths in a shared environment for the benefit of other people. The word is also commonly used to refer to the kinds of activities that maintain these feedback paths in place. Thus, work activities produce some kind of environmental stabilization, the creation of some atenfel, molenfel, or molenex, which can then be used in controlling other perceptions.*

The workers who do these things are controlling for various different things, such as perceiving their reception of a paycheque, but seldom would they control for perceiving an increased ability to control by people they will never know.

The stability of the public value of a franc is of this kind, in that it helps unknown other people to control some perceptions better than they would in the absence of that stability. Within reason, people can rely on being able to trade a certain quantity of francs directly with someone offering goods and services that they want, and know with little uncertainty whether they are making a fair trade. Since francs have a stable trading worth in future trades, it is much easier for a person wanting a haircut to trade for one if

they know Tam will trade a haircut for one franc than if they have to work out with Tam a fair trade using other IOUs.

A publicly accessible stable average trade value of a franc against each other type of IOU reduces the uncertainty of the value of any trade to both parties, because they can each look up the public average value of the other type of IOU. The more public and more stable the franc, the more value it has in trades. Francs soon become a common medium of trade. Francs (not the paper they are written on) are embryonic money. Francs have the same kind of time-binding property as writing. Indeed, they are writing on some suitable form of material such as paper, but possibly metal (coins). In the way writing passes general information through time, francs pass value through time.

Soon most trades use francs rather than specialized IOUs, so Frank retires the unwanted IOUs he receives. He writes new francs at the now stable exchange rate, and burns the IOUs. He can write as many as he likes, but if a client perceives that a franc has less value to Frank than it did when Frank wrote it, the client is likely to require more of them for an IOU she offers in trade. When people offer francs in trade for work/energy, the product will serve them as means to control whatever perceptions they later want to control. That work/energy does not get devalued when Frank writes too many francs, but it may become devalued over time, as the products decay and require ongoing maintenance.

When Tam uses in a later trade the francs she obtained by giving an actual haircut, she has done exactly as she would have done before Frank set up his IOU exchange. There's a difference, though: When Tam redeems a "Tam haircut" IOU, she no longer owes a haircut to anyone. The specialized IOU was converted into work.

When Tam accepts some francs as a fair trade for a haircut, the francs remain in circulation. No francs were lost by having been converted into work or goods. Tam didn't owe a haircut before she gave one in exchange for francs, and she doesn't owe one afterwards, either. But now Frank owes Tam, whereas before the haircut, he owed Tam's client.

III.9.6 Networks, atenexes and infrastructure

Frank's francs have become very flexible atenexes that incorporate an almost unlimited number of atenfels, each of which is designed to help anyone who has some to control a wide variety of perceptions. In order to use an atenfel deliberately in controlling a perception rather than just as a passive part of a reorganized environmental feedback path, an organism must have reorganized so that its control hierarchy contains a control unit that controls a perception of the atenfel *as* an atenfel. A franc is not being used as designed if the paper on which it is written is used to clean up spilt milk. The paper is indeed the environmental part of an atenfel, but in using it as paper, the atenfels that could have been provided by the writing on it are lost. The franc is a "tool" designed for a specific purpose.

This by no means is equivalent to saying that for every aspect of the environmental feedback pathway there is a controller in the organism that can perceive and use it deliberately for control. For example, in order to create text on a computer screen by typing on a keyboard, the typist needs the skill to see that a keyboard may serve that function, and the skill to select the desired letters on an available keyboard. But the typist probably knows next to nothing about how the pressure on a key-top results in a letter appearing on the screen. It just appears.

Someone else, some time previously, had to perceive how the pressure on a key-top might be made to cause a letter-shape to appear on a screen; someone had to perceive how a screen could be made that would allow that letter to appear, and someone had to perceive how circuits built of structures designed by others could be fitted together to link the signal from the key to the screen at the right time and place.

Those someones were most unlikely to have been the same person, but the controlled perceptions were all controlled by the same Role, “Inventor”. The person who controlled a perception of as yet non-existent screens that would allow a letter to be displayed was probably not thinking of letters, but of arbitrary patterns of light, shade, and colour.

The person designing the keys on an electronic keyboard probably was not interested in their appearance on a screen or a piece of paper, but they probably were controlling for the keys to be useful as atenfels for people in future to use in controlling various perceptions that probably would involve displaying text. Whatever the intention of the key designer, the result is that the key design can be used by the constructor of, say, a computer, to offer a stable feedback path between finger and screen display. This stability is of the kind described by McClelland in the passage quoted in the introduction to Chapter II.4, such as the stable existence of a road that can be used by anonymous car drivers in controlling their perceived location.

Eventually, the side effects of what the inventors were controlling for are linked together as just one atenfel — a computer — in the environmental feedback path of someone who is controlling for expressing ideas in readable words. The keyboard and the screen can be linked together only by using many inventions made by other people who were not controlling for letters to be transcribed from finger pressures, nor for the shapes of letters to appear on screens.

That all of the components were probably invented to serve other purposes besides that of an author suggests that they are components of the network of interacting possibilities that we call “infrastructure”. Infrastructure enables possibilities, as opposed to the designed atenfels of something like a hammer, which is designed to drive nails, although having properties such as weight that allow it to be used for other purposes.

An atenfel is a connection in the environmental feedback pathway between the output and the perception, so those two end-points give the atenfel an identity or label. All the atenfels in the same path would have the same identity in that respect. However, some exist in the feedback path only when used in parallel with another. The couple is called a molenfel, as we discussed in Chapter 5, and though the component atenfels may serve some purposes, the coupled molenfel can be used to control perceptions that are not available for control using any of the component atenfels without the others.

A paved road is not much different from a forest path if you do not have a wheeled vehicle, and a wheeled vehicle is not much better than walking if you don’t have a suitably prepared road surface. Cars together with the roads they run on form molenfels that serve the perception of oneself being at a distant location. The label applies to the {car+road} molenfel as a unit, not to its constituent atenfels car and road, just as the taste of salt is that of sodium chloride, not the taste of sodium added to the taste of chlorine. For most purposes a molenfel can take the place of an atenfel that performs the same function in an environmental feedback path, perhaps more efficiently or rapidly. Almost all inventions are created by combining pre-existing atenfels, perhaps together with a novel one, into a novel molenfel.

Inventions may be freely available for use, but more often than not their use is an abstract object of trade. One trades money for the right to use a patented invention or a copyright pattern of words in a text. The usual properties of a trading protocol apply. Both parties must perceive that it increases their worth by making the trade — that they gain more value than they lose thereby.

In the discussion of side-effect loops in Chapter xII.14, the beneficial side-effects are said to be the provision or modification of atenfels. If the atenfel is a CEV of a control unit in the benefactor, why is there not an opportunity for, or better, an expectation of, conflict? The answer is that there is indeed an opportunity for conflict, which sometimes becomes real:

“Let me help you.”

"No, I want to do it myself."

or perhaps

"I wish you wouldn't keep showing me how to do everything. I want to figure out how to do stuff for myself."

Usually, however, there is no conflict when the benefactor controls a perception of an atenfel in another controller's environmental feedback path. The other might not even notice until later, as would be the case for the author who uses a computer when writing a book, without having in any way participated in the design or construction of the computer or its components. For another example, a host expecting several guests for a meeting may bring into the meeting room several chairs, which are atenfels for the guests' controlling for perceiving themselves to be seated, but the guests' control units become active only after the guests arrive.

If the host has miscounted, and sees that one of the guests has no chair to sit on, there is usually no objection if the host goes and gets one rather than telling the guest where one is to be found. The guest uses the host as an atenfel for one perception — perceiving a chair to be available — and the chair as an atenfel for another, perceiving herself to be seated. The guest does not go searching for a chair when she controls for perceiving the chair to be available but it isn't. Instead, she displays to the host that she would like one to be available. They use a protocol, which might well be non-verbally implemented.

Any one ECU is likely to use several atenfels for control. One PCT mantra is "*Many means to the same end*." Concomitantly, different atenfels may participate in several higher-level loops. The same means may be used to support a variety of ends. In atenfel networks, the nodes need not be of the same type, and usually are not. For example, one can do much more if one has at hand a hammer, a saw, a drill, a screwdriver, some nails, some screws and some wood than one could do with any one of the items individually.

The networks we have been discussing consisted of the benefits conferred by one control system on another's ability to control through side-effects or intended effects of control. Now we look a bit more closely at one aspect of this, remembering that the benefits (and detriments) are in large part determined by how one control system affects the usefulness of particular atenfels to another: "*If I am using a hammer, you cannot use it at the same time, but when I am finished, I may lend it to you, and if I do, you might not need to buy one"*.

Constructed artifacts, though designed to provide atenfels for specific purposes, can be, and usually are, atenexes. Some of them can be used for so many purposes that they are called "infrastructure". In the language of Social Network Analysis, infrastructure atenexes are nodes of "high centrality". The electricity supply system is a good example. Many people have experienced the chaos that occurs when there is a major stoppage in the supply. The set of perceptions one can control becomes markedly smaller the moment the electricity goes off.

One consciously notices not the perceptions one can control because electricity is available, but the ones one cannot control when it goes off. Water supply is another system we call infrastructure. Being able to get water by turning a tap is a very different proposition from having to carry a bucket for three hours to find water in a dirty well. But if the electricity supply to the pumping station goes off, one may need to resort to the bucket.

We can add many other constructed artifacts to the concept of "infrastructure". What they have in common is that they are large atenexes, offering a great many different atenfels, but are not usually themselves the CEV of any perception their users control. Yes, there are people, as McClelland notes,

who work at creating and maintaining the infrastructure components, but their number is small compared to the number of those who simply use them in controlling other perceptions.

Beyond these, we have even larger atenexes, intangible ones such as money and language, which provide enormous numbers of atenfels. Although one can see, touch, and feel the physical tokens that represent money, one cannot do that with the actual money, which is the value or worth of the physical tokens.

Money is an atenfel hub or atenex *par excellence*, to such an extent that many people, such as bankers and financial advisors, play roles in which they are given money for controlling perceptions whose environmental output is only the manipulation of money. The same is true of language. Each is a core component of most human cultures, corresponding to the core status of carbon in the wide range of molecules that occur in biological organisms. Carbon by itself is not very useful (even if we remember that diamond, graphite, and graphene are pure carbon), but carbon compounds are useful for almost everything relating to living things.

Infrastructure atenexes have another characteristic in common. They have the ability to serve a very large number of perceptual control loops at the same time, and a high proportion of the populace has access to them. Most of them are capable of indefinite subdivision. One may use 4 milliwatts or 400 watts of electricity to illuminate something. To buy something, one may use $0.50 or $50,000. But if too many people simultaneously choose to use 400W lights along with air-conditioners, washing machines, and the like, the power available to all of them may suddenly go to zero as the power station overloads.

Simply to describe money (or language) as an atenex like any other is to shortchange it. In network analysis, most nodes are hubs in the sense that they have more than one in-link or out-link, but different nodes have more of them. Money and language both have an unlimited range of potential inlinks and outlinks, to the extent that they might almost be called Universal Atenexes.

One way to describe the nodal nature of an object or an abstract artifact is to list its in-links and out-links, defining the in-links as the action outputs of ECUs that use the artifact and the outlinks as the perceptions influenced by those actions in those same ECUs, ignoring side-effects when considering only the control of that particular perception.

The side-effects of using an artifact as an atenfel may well influence other perceptions that are controlled using that same artifact, and in a complete network analysis they must also be considered to be out-links. Indeed, they will often contribute to the tensegrity effects of social interactions. But they are not of interest to the immediate discussion.

The physical properties of a material object, such as its size and weight, limit how it can be used for control. Unless some other tool is used, a rock weighing more than a few kilograms can not be used in a way that requires it to be lifted, but it can be used as a pedestal for someone to stand on. There is no such limit, however, on the perceptions that might be controlled using that object. One can imagine numerous perceptions that might be better controlled by someone standing on the rock than by the same person standing beside the rock, ranging all the way from haranguing a crowd to seeing over an obstacle, to testing one's sense of balance.

In the previous paragraph there is the phrase "Unless some other tool is used". A "tool" is usually a constructed artifact, though it may be a found object, or, indeed, another person who controls some perception in a way that produces the effect of a tool. As McClelland pointed out in the extended quote, management expertise is a tool if the person with the ability allows it to be used in a variety of protocols to serve different perceptions controlled by other people.

Subordinates may ask questions about what is expected of them, superior managers may ask for certain goals to be achieved, interactions with similar-level managers may avoid conflict and benefit the operation, and so on and so forth. The skill of the manager lies largely in appropriately deploying protocols that achieve results wanted by the superior while maintaining the effectiveness of the subordinates, avoiding potential conflicts and maintaining high morale.

A tool, by definition, provides an atenfel that changes the way that output actions influence the CEV (a lever), or the way the CEV influences the perception (a magnifying glass). But as with other artifacts, most tools can be used to control a wide variety of perceptions, and therefore do not simply provide individual atenfels. They are atenexes with great "fan-out", in the sense that the limited possibilities for direct influence on the CEVs offered by the person's muscles are multiplied by the tool to allow influence on many more different CEVs, as suggested in Figure III.9.1. The important point is that once a tool has been invented, a whole new range of perceptions can be controlled.

A Role is in the same sense a tool. The cashier Role is a tool for the customer who wants to pay the company for some purchase. The cashier person is not the tool; the cashier Role is. But the cashier person has other roles that are linked to the cashier Role, such as Employee. The Cashier person has many roles that are not linked to the cashier Role. Perhaps the cashier is an after-hours tinkerer, playing the Role of Inventor. What does the Inventor Role require of the cashier's social environment? What tools may help the person playing the Inventor Role to produce something new to that person. The person can never know whether the invention is new to the world. To discover whether it is new is one part of the Role of Patent Examiner. In Chapter III.10 we will look at invention and inventions a bit more closely, in connection with the "Commons of Ideas".

III.9.7 The Trade Motif, Cheating and Coercion

In Section III.9.4 we described "fair trade" as a use of the Trade Motif of PCT as a means of adding Value to the "Worth" of both parties, but we did not discuss unfair trades, in which one of the parties loses Worth. We do so now, noting that there are at least two distinct kinds of unfair trade. We can call such trades as being between Walter (the winner) and Val (the victim). It is also possible but would be unusual and not necessarily unfair if both parties lost Worth by making the trade.

Why might someone control for perceiving a trade to be agreed if they would thereby lose Worth? One possibility is inherent in the Trade Motif itself (Figure q29.2). For both parties the perceived Value (increment to their imagined future Worth) has a range of uncertainty that depends on unknown future events. Sometimes events will occur that had a prior probability outside the range either or both parties included in their agreement to change. If this was true for both parties, but only Val lost Worth because of the trade when the low-probability event occurs, the trade was fair, but turned out better for Walter than for Val. Val might be a victim, but one sometimes called "a victim of circumstance" like a pedestrian killed while standing on a sidewalk by a car whose driver had a heart attack, just unlucky, not the victim of any malicious intent.

Trades can be imbalanced, both gaining Value, but Walter gaining a lot more than Val by making the trade. Walter might, for example, buy an item for a dollar in a jumble sale. Val gets the dollar for what she perceives as a piece of junk, but Walter has it appraised at an antiques show and is given an expert opinion that it could fetch thousands of dollars at auction. If Walter did not perceive the item as having monetary worth, but bought it because of its pretty shape, the trade was not unfair, but if Walter recognized a signature on the item as being by an important designer, and perceived that it was likely to be of great value if it was not a forgery, the trade would be unfair.

When one party to a trade (Walter) has relevant information that the other (Val) does not have, the trade is inherently unfair, but Val might make the trade even knowing this disparity, which is the normal case between a commercial seller and an individual buyer. A farmer will sell his produce for less than his cost of producing it, because the alternative is to get nothing in return for that "sunk cost". The buyer gains more Worth, the lower the price offered to the farmer. The buyer is not cheating, but is coercive, as we will argue below. Cheating can occur even in such a coercive situation, if the buyer falsely says something such as: "*I don't like to offer so little, but I can't sell it onward to the grocer for more, because I cannot get any more for it than just enough to cover my transportation and distribution costs*" when he actually believes that the grocer would in fact pay a lot more.

It is almost always true that the two trading partners each know something the other doesn't that might be germane to the trade negotiation. Seldom do two traders come to a possible trade knowing exactly the same and estimating the uncertainties identically about the future values of the traded items. We do not usually call this kind of imbalance in knowledge either cheating or coercion, although the disparity would be expected to affect the trade eventually settled on.

Why not? One possible reason is that it is be an aspect of every trade, and can therefore be treated as "random noise" that contributed to the future value probability distributions each party attributes to the two items. Neither party can accurately perceive what the other knows, and it just contributes to the uncertainties involved in agreeing the trade. There are, however, exceptions to this general rule, which is when the disparity is well above its normally acceptable range. One party offers a pretty stone, which he agrees to trade for a pack of cigarettes, while the other recognized the stone as a marvellous emerald worth many thousands of dollars in his next trade back home.

At the moment of the trade, both perceive themselves to be getting more value than they are giving, so they perceive the trade as being fair and uncoerced, but an unbiased knowledgeable observer would see the difference in future values to the two parties as grossly unfair. Walter, receiving the emerald and having a reasonable perception of its future value in a trade, perceives himself as winning, while Val also thinks he is gaining value on balance, when in a larger context he is not, because he could have traded it to someone more fair than Walter for a boatload of cigarettes if he wanted. The "more fair" trader (Francis) would tell Val that he held a very valuable stone, valuable in the sense that Francis would be able to get a great deal in a future trade for it back home (as would Walter, who did not tell that to Val).

This kind of "cheating" is just an aspect of "breaking the rules", which determines cheating in a game where the rules are written down or agreed beforehand by the players. The rules in the "emerald for cigarette" cheating trade are not written down. They are "moral rules" controlled by the collectives to which the trading parties belong, and they might not be the same to both. Indeed in the kind of trade exemplified by the "emerald-cigarette" trade, I imagine the cigarette-offerer as a European and the emerald-offerer as a South American or African native.

In Section IV.5.2 we will see that at least some rural US children consider it immoral to treat one's peers badly but moral and proper to treat badly those over whom one is "better" for no other reason than having been told that people with their eye colour are "better" than those of a different eye colour. Our covetous European probably perceives himself to be "better" than the emerald-holding native without a gun or even "proper" clothes, and therefore morally entitled to make a trade that would be considered cheating if the other party had been a European of similar class.

Be that as it may, a key point is that in a "cheating" trade, both parties believe they are gaining sufficient Worth to make the trade acceptable, reducing any error they might have had in controlling their own perception of their Worth (an element of their self-self-image). This would not be the case in a coerced trade. In a coerced trade, Walter perceives himself to be gaining Worth, while Val perceives the

trade to have negative Value — he perceives himself as less able to control his perceptions in total after the trade than before.

If Val knew the potential value of the pretty emerald-stone that he has, he would be unlikely to trade it freely for a pack of cigarettes. But if Walter were to tell Val that he would spend the rest of his life in jail if he doesn't hand over the emerald, Val could imagine a much greater reduction in his Worth by being in jail than he would lose by disposing of the emerald. Val makes an "internal trade" between handing over the emerald and spending his life in jail, and hands over the emerald even though the stone-for-cigarette trade loses him some Worth.

Here we see coercion as another aspect of the Trade Motif. Walter offers Val a trade in the environment that Val is likely to use as a unitary item (make or don't make the environmental trade) in an internal trade. Such internal trades are likely to occur in both parties to a normal fair trade negotiation. The difference in a coerced trade is that Val is not given an opportunity to negotiate an outcome that does not cause him to lose some Worth. In a fair trade he has that opportunity.

Can there be coercion without the victim performing an internal trade between the Value gain or loss when controlling for performing the actions demanded by the coercer and the Value gain or loss by doing something that uses actions incompatible with what the coercer wants? Is it possible to coerce a living control system that has no imagination? The trade motif requires imagination, so to answer that question in part, we should seek living control systems that perform variable trades. Trades that are performed as an apparently invariable ritual may be examples of collaborative control with reciprocal benefits, developed in the course of evolution because both species have more surviving offspring if they collaborate by this particular trade than if they don't.

Are there such links in biological ecological networks? I do not know, but I suspect there must be.

III.9.8 The Trading Value of Relationships[41]

Thus far, we have defined the incremental perceived Worth, the Value, of a trade as that provided by the change of ownership of the items traded. There is, however, an intangible component to the Value of a trade to either party, and this Value must be included in the agreement on a fair trade. This intangible component is in any change the trade might make in the relationship to the other that each perceives. If Val thinks that by making a apparently (to an outside observer) coerced trade with Walter, he will gain Walter's goodwill and support in some future activity, to Val the trade is of higher value than it might have been if Val never expected to meet Walter again.

Consider this as though the possible traders were our old friends Bud the Butcher and Tam the hairdresser. In the trade we discussed, Tam offered Bud a haircut and two haircut IOUs. But suppose instead that Tam offered her goodwill, in the form of offering to spread the word to her customers about how nice Bud is to trade with, and how great his steaks are. Tam suggest to Bud that her goodwill and the resulting advertising will have at least as much Value to Bud as would her two IOUs.

Val and Walter both have other relationships that involve interactions, but the added Value to Val does not depend on the specific perceptions related to the conflicts involved in the trade. It depends on Val's perception of how much more likely Walter is to cooperate with him if Val tries to initiate a future protocol involving a random perception Val might be trying to control using Walter as an atenfel, or if Walter perceived Val to be some difficulty (apparently trying without success to control some perception).

41. The concept of relationship advantage as a component of Worth was suggested to me by Bruce Nevin (Personal Communication 21.11.06)

This is a perception perceived by Val, not Walter, who has his own perception of the added Value to himself of a changed relationship with Val.

If the trade is fair on the basis of the Values to Walter and Val of making it, any positive Value accruing to a possible change in relationship is "gravy". However, Values may be negative, too. Suppose Val has friends that might control for their friends (including Val) not trading with Walter, Val's relationship with those friends might suffer, in the sense that they would be less likely to help him when they perceive him to be in need in the future.

Imagine as an example that Walter is an employer and Val and his friends are Walter's employees, who go on strike for more pay. The trade Val makes with Walter is that Walter offers Val a raise that Val considers adequate, which Val trades for an offer to return to work. His friends are likely to call Val a "scab", and ostracize him. That trade with Walter improves Val's relationship with Walter, but not with the previously friendly strikers, if they perceive it to have occurred. Val must consider the discounted total future Value of all these relationships in determining whether to agree this particular trade with Walter. People differ on how much Value they perceive for short-term effects as opposed to long-term ones. Most strongly discount future reductions in Value as opposed to instant and short-term Value increases.

We here introduced the explicit notion of time into the Trade Motif. So far, we have ignored time except to say that the Values involved in the interlocking conflicts of the motif are probability distributions of future contributions to the Worths of the two parties. Time, however, is always involved, whether explicitly in the form of "I'll help you for an hour, and then I must stop" or implicitly because unexpected environmental effects are always possible, and the further in the future one looks, the more probable it is that some such effect will have occurred by that time.

The classic "Faustian Bargain" is of this time-bound kind. Faust trades his eternal soul to the Devil in exchange for a long, lucky, happy, and wealthy life. He gains much Value in the trade, but only for his long lifetime, whereas the Devil gains his soul for the rest of eternity, but not until the end of Faust's life. Faust has gained a good relationship with the Devil, which increases his lifetime Worth.

When Faust makes the bargain, he perceives himself as the winner in the Trade, since he gains considerable immediate Value, and any reduction in his Worth will not occur until far into the future. At the time of the trade, both see themselves as winners. Faust amortizes the Value of the trade at a discount rate that means his lifetime benefit far outweighs his later eternal loss, whereas the Devil, with his eternal lifetime, does not discount the future increase in his Worth at all.

We see many, similar time-based Faustian bargains in everyday life. Trading money wealth for future reduction of the livability of the planet is an obvious Faustian bargain, if the purveyors of fossil fuels control for the future welfare of themselves and their descendants. Or we could consider the executives of those companies and of companies selling tobacco to be the Devil, and Faust as members of the public who fail to act to prevent the activities of such companies, revelling in the pleasures of smoking or of plentiful power supplies now, and accepting the probable perceptually far future large reductions in their probable Worths.

Many Value changes are based on discounting the future, but with the assumption that improved relations last a long time as compared to values that might be perceived by an external observer. If I ask you to come and hold something for a few seconds, I probably will not give you anything explicit in exchange, but I will perceive you as a "good guy" if you hold it for me, and expect that you will perceive that I so perceive you, and therefore am likely to do you similar favours at some unknown future time, not as a *quid pro quo* trade, but on the basis of maintaining good relationships.

If relationships have Value that can be included in a Trade, that added Value cannot be perceived by an outside Observer. The commodity/service Value may be, so a Trade in which Val perceives considerable

relationship Value may seem coercive to the Observer. Political situations frequently provide examples, as, for example, if a party member trades acting in the way the leader wants in exchange for the perceived goodwill of the leader in the next election or in elevation to a Cabinet position. If this involves much change in what perceptions and to what reference levels the party member controls, the member's friends might accuse him or her of "toadying" to the leader, reducing the Value of their relationship with the "toady". The member who anticipates this effect but continues "toadying" is performing an internal trade, with all the conflicts inherent in the Trade Motif.

Chapter III.10. Energy, Money, Inflation

Continuing the PCT just-so story about how money may have evolved through barter trade and the invention of the IOU, we move to more secure ground. Control takes energy to move entropy from some controlled variable to the wider environment, and more energy to maintain a low value of mutual uncertainty between variations in the values of reference and CEV. Reduction of entropy is the creation of structure, as we discussed in Chapter 12. In this Chapter we use these thermodynamic relationships together with the ideas developed in the last Chapter to augment our PCT view of money in society.

III.10.1 Work and Structure, Investment

Everything tangible that we use either is provided free by Nature or is the product of various people having controlled perceptions of how they want to structure something already worked on by other people. Since we do not pay Nature, all we ever pay for is the work others have done in controlling their perceptions. The same is true for non-tangible structures of thought, whether they be works of art or scientific theories, which do not contain in their structures any materials provided by Nature. This includes the work done by the maker and the maker's teachers as the maker acquired the skills to perform the process.

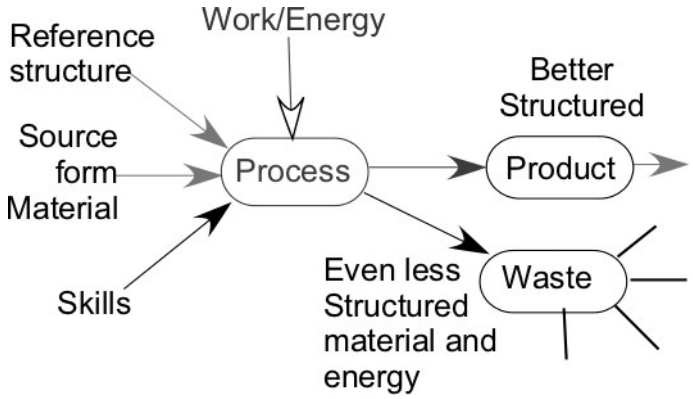


Figure III.8.1 The basic flows in the process of making something from some earlier state of the material. The Maker controls for perceiving the structure that is wanted. Using skills to take advantage of atenfels, the Maker expends work or energy to change the entropy of the source material into a product that is more structured than its original state and waste products that are usually less structured than the source material.

As we discussed in Chapter 12, "structure" is a measure of information, the reduction of uncertainty about some components of the structure when other components are known. To create structure requires some of the energy used to be incorporated as a kind of potential energy that holds the structure together. Energy and entropy have a long understood relationship in the thermodynamics of bulk material, and Boltzmann showed that in a uniform gas the same relations could be derived from the statistics of the interactions among gas atoms or molecules.

In a non-uniform material, only the statistical approach can be used. This implies that another way of looking at the process flow is as an informational flow, the flow of information that has already produced the Maker's skill set and the flow from that into the structure of the material from source to product. This process-centred structure is a different way of looking at the functioning of a control loop or a control

hierarchy, focussing on the energy and information aspects of control rather than on the usual view of the functional circuits around a control loop or a collection of interacting control loops.

People trade only for the work of others, even if that work is only the selection of a gemstone washed up on a beach. Nature's products come free, but people's work usually adds to their value for other people — the increase in worth that they supply to a purchaser. The inputs to a process that produces a tradable product are the raw materials and the skills that allow the producer of processor to use energy to form a product that is structured like a reference structure. The product might be a haircut, a student's control hierarchy, a mechanical tool, a work of art, etc.

Returning to Tam, the haircutter, her work may build on much prior work of many others. When Tam expends energy to cut a client's hair, she already has on hand the necessary tools and in her control hierarchy the necessary skills to use them. She does not have to learn every time a new client arrives how to make tools and then make some, nor to learn anew how to use them.

Every client can take advantage of the accumulated energy investment in Tam by a long line of makers, inventors, learners, teachers, and indeed parents and earlier ancestors. She had acquired her tools and skills by her own work and by trading for the accumulated energy investment of other people (Figure III.9.2). As Tam perceives it, she acquires structure, the tools and skills that result from energy investment by investing some of her own energy in learning the skills and acquiring the correct tools.

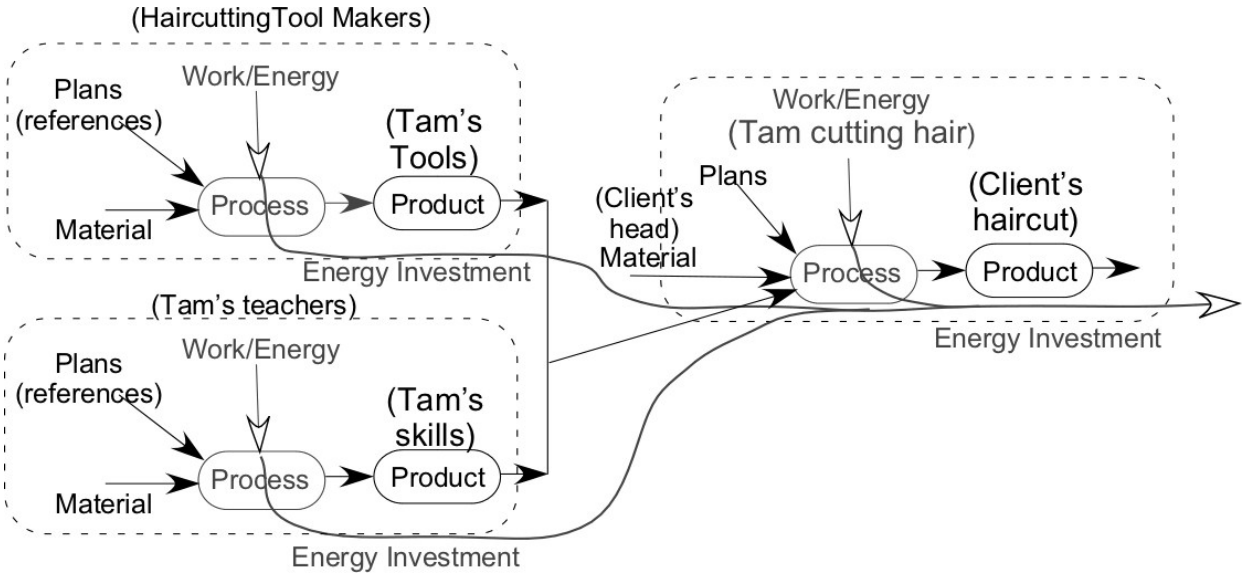


Figure III.9.2 How energy investment can propagate, using Tam's haircutting as an example. For Tam to be able to cut hair sufficiently well to have a client who will trade for her services, she and her teachers must have invested energy in producing her skills. No matter what skills she has learned, she cannot cut a client's hair unless someone else has invested time and energy in creating tools specialized for haircutting. Her invested energy might result in a client with well-cut hair landing a job for which an ill-kempt person would not have been hired.

What she trades to her teachers and her toolmakers for her newly acquired skills and tools might be some barter item, or in the form of IOUs or Frank's francs. The investment she is making, however, is not ultimately measured in money or francs, but in ergs, energy expended in creating material or abstract structured product. Later we will find that there is a close relationship between the investment in work/

energy for structure creation and an investment in money or francs, but we have as yet only incompletely laid the foundation for that claim.

We can at this point fully accept that structure can be abstract, since part of the work done by others is, to Tam, just to increase her own skills, reducing her uncertainty as to what she could do if she wanted to produce a hair cut of a given style. If her teachers have incidentally at the same time taught other hairdressing students the same skill, from Tam's point of view that is energy wasted by the teachers (not shown in Figure III.9.2) if she perceives it at all.

Each of the stages in Figure III.9.2 represents a complete instance of a trade motif of perceptual control (Section III.7.6), though the diagram shows only one side of the trade. The teachers and tool-makers did not contribute their work/energy and know-how for free. In some manner, unless they were coerced, they gained more value from the transaction than they lost. In other words, somebody paid them to provide Tam with the skills and tools. That somebody was not necessarily Tam. It might have been an Authority or GVC who perceived that its members would gain more from Tam's gaining the ability and means to cut hair than by leaving her to fend for herself.

Either Tam or the anonymous GVC or Authority made an investment of the time and work that paid for her training and tools. It was an investment in the value that Tam's future work might create for her clients. Putting this in other words, Tam converted the work-energy others expended in training her skills (her reorganized control hierarchy) and creating her physical environment (her tools, her workplace, etc.) into the means for her to control her perceptions of a client's hair shape. All of that was their investment in her future benefit to them.

Tam's return on investment is what she receives in trade when she cuts a client's hair (Figure III.8.12). If she did not pay out of here own means, but had her training and tools paid by a GVC or Authority, the benefit they get from possibly not having Tam do "bad things", and from having various people get good haircuts, the return on investment is theirs as well as Tam's. It is the energy they do not have to use in controlling for things Tam has done or may do.

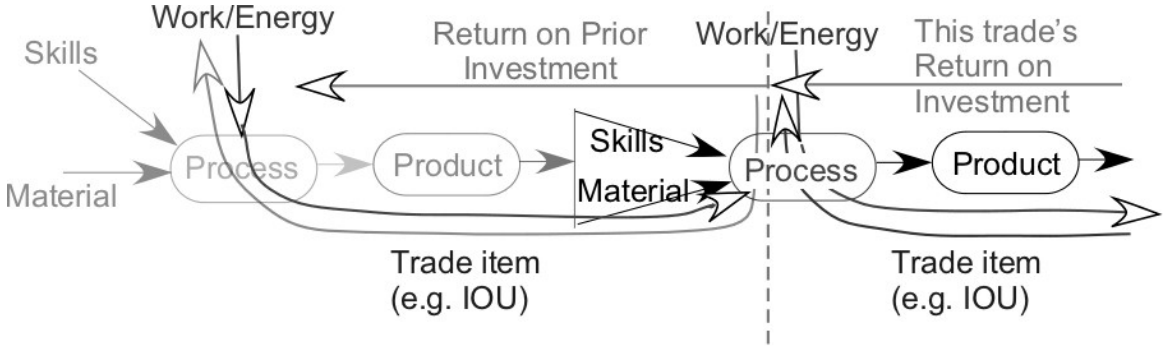


Figure III.8.3 Return on Investment is not necessarily money, but it is value. Here it is shown as being manifest in an IOU, but it could equally be in the investor's perception of having increased worth because of the process in which the investment was made.

III.10.2 Decay and Maintenance

In the McClelland quote at the head of Chapter II.4 to which I often refer, he says:

> *In some kinds of work, people maintain feedback paths rather than creating them. People doing this work take the existence of certain feedback paths as perceptions to*

be controlled and then seek to protect them against the ongoing effects of disturbances. The janitor cleaning a building, the systems engineer fixing software bugs, the emergency responder driving an ambulance, or the baby's caretaker changing a diaper, all work to maintain feedback paths for others. Thus, the feedback paths in our shared environment depend on constant human attention and effort to do the work necessary to keep them stable. Without continual work, a humanly structured environment begins to crumble over time, like ghost towns or ancient ruins. The environments that most people live in are filled with feedback paths, both physical objects and routine actions, that have been shaped and maintained by human work.

All products are subject to the inevitability of decay. Hair grows back within a few days after a haircut, skills decay after years of disuse, building collapse if left untended for decades or centuries. We consider the implications of the fact that all structures are subject to decay as their initially low entropy increases because of the effects of external events, which are far more likely to be damaging than to be useful in restoring the structure to its original form (Chapter 12). Control of the perceived form of this structure can oppose this decay, continuously correcting for externally caused differences between the perception of the structure and its reference form (disturbances). If work/energy is used to repair and maintain them, many products can be kept for a long time in near new condition.

The maintenance loop (Figure III.8.4) can be seen both by itself as a conventional control loop and as part of a "create-maintain" motif that includes both the perceptual controlling of the original creation of the product and its maintenance. This is a social motif, since maintenance is typically not performed by the original creator, and is certainly not performed by the creator Role even if the creator and maintainer roles are played by the same person.

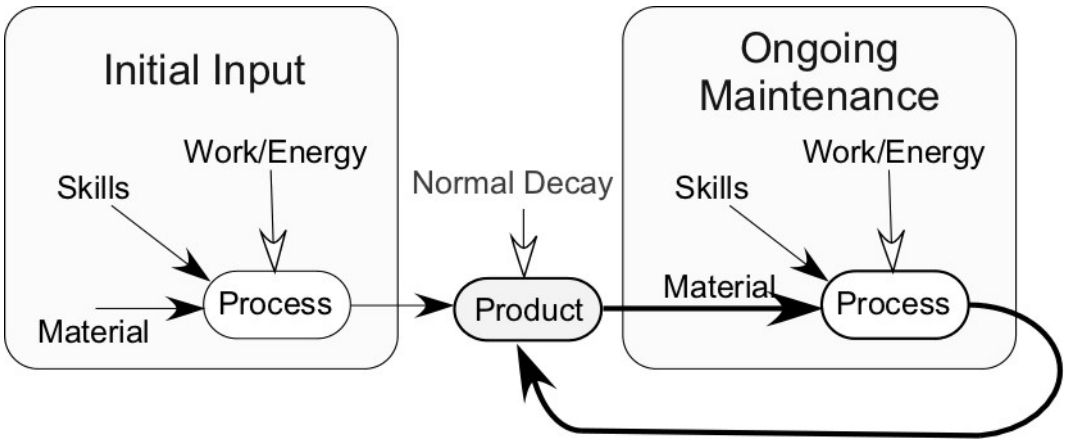


Figure III.8.4 The create-maintain motif. By itself, he maintenance loop is a simple control loop. In this part of the create-maintain motif, work/energy input is used throughout the life of the product, so long as someone (or some GVC) is controlling for the structure to be maintained in good working order.

The maintained product retains its original property values and usability as a means for its user to control perceptions, but only does so by continued import of energy for control during maintenance. If the structure is left unmaintained, it will lose its value. It may also lose (or gain) value because of changes in other atenfels available to the owner that were not available when the product was originally acquired.

Think of the once cherished toys that you long since put aside, or the training wheels on your bicycle that become a nuisance when you acquire the skill to ride using the physical properties of the bicycle without them. The toy lost its value because you no longer want to play with it, the training wheels because for control of the same variable (perceiving oneself riding without falling) they were once essential but have become an inhibitory component of the environmental feedback loop.

We return to considering the trade in IOUs that in the last Chapter reached a stage at which Frank would buy and sell specialized IOUs at a pre-specified rate. A franc is a product of Frank's work in finding the kinds of IOUs his customers want. As a product, it will decay like any other, but how, especially after most producers have turned to trading their work/energy for francs rather than their own specialized IOUs? Each maintenance episode involves a trade of francs for work. In every trade, the relative values are uncertain, with the result that the same work requires more francs each time it is performed. Franc inflation measured in units of work/energy may be slow, but it is inevitable.

The number of francs required for maintenance is a rate, so many francs per year, in contrast to the simple number of francs required for the initial trade of a new instance of the product. This difference implies that enough francs must always circulate around the maintenance loop to allow fair trade for the maintenance work/energy rate required to sustain a steady state of product availability. To produce new product requires additional francs, just as did the production of the first instance. Frank must keep writing new franc IOUs for all these needs.

More and more francs are continually being required if the average worth of the people in the community is to be kept stable. Even more are needed if their average worth is to be enhanced. But every franc IOU newly written by Frank adds to the debt that he owes to whoever holds it. Most francs are now traded for product, not for IOUs which few people now want. This means that Frank cannot repay his debt in the form of the old specialized IOUs as he used to do, and he does not acquire product through his trades.

So what now for Frank?

III.10.3 Banking, Saving and Lending

What now, indeed? Frank has to do something about the loss of his trade in specialized IOUs. Let us suppose that he starts a lending service, lending people francs they could trade for their current needs. They give Frank an IOU promising to pay the francs back at some defined time, plus a fee for Frank's work, plus a new added fee Frank calls "interest". Frank adds "interest" because he wants to receive later at least as much value as he lends out, but the uncertainty of the future value of a franc means he does not know how many francs he must ask for when the borrower pays off the loan. He must assume that francs will have less value with respect to work/energy as time goes on, because of the uncertainty involved with each individual trade. Frank charges interest on the loan at a sufficient rate to cover his uncertainty about the future public value of a franc.

Francs are taken out of circulation when someone keeps them under the mattress as savings. They are of no use to anyone else when they are held that way, and they tend to lose value for the owner because of the inflation we have shown to be inevitable. But if savers lend the savings to Frank for safe-keeping, he could lend those francs out again. Frank charges a fee for keeping those francs safe. He may also pay interest to those who entrust their francs to him. but it will not be as much interest as he would ask were they to borrow the same number of francs, because he is also providing a service in offer a place to keep them safe for the client — safer that in some hiding place in their home, at least.

At this stage, Frank's francs have most of the attributes of money. One could almost call them money. What do they lack? *Trust*

A franc still represents a debt Frank is committed to repaying to the holder, but since he no longer can pay in specialized IOUs, he has to acquire some product likely to be accepted by whoever demands repayment in future. Ideally, that product has minimum work/energy invested in its structure, because the person demanding repayment might not want that particular structure. It should ideally be contributed directly by Nature with a minimum of work/energy used in its extraction and refining, not decay over time, and be indefinitely divisible. Gold is almost the only substance fulfilling these requirements, and in the real-money world, many people are willing to accept a weight of gold in exchange for the IOUs that are money.

Frank may acquire a quantity of gold in case someone insists on repayment of the debt implied by his francs, but ordinarily he would not need to, if his francs have a stable value (Section III.7.7). But to keep the trust of his clients, he is likely to keep some on hand. Likewise, when clients entrust him to keep safe their own saved francs, Frank must ensure he keeps enough francs (not gold) on hand to repay the greatest number of people he imagines might all want their savings returned at any one time. Almost always, those would be a small proportion of the people whose savings he is keeping, so Frank can write franc IOUs for a multiple of the number entrusted to his safe-keeping.

Keeping large quantities of paper francs and metallic gold on hand for use in everyday transactions is rather inconvenient, and Frank has another brilliant idea. He suggests to people who bring in their haircut IOUs that instead of giving them a paper two-franc note, he might just write in a book that they have given him the IOU in the value of two francs. If they want to use one or two francs to buy something, they can come to him in company of the seller. He will write in the book that the seller has two more francs and that the buyer now has two fewer.

The franc is now identifiably linked to its owner, or rather, the number of francs owned is identified with the owner. A particular piece of paper is not, and Frank has not had to do the physical work of making the franc IOU piece of paper. Of course, in exchange for this service, Frank will accept some part of a franc as a fee. Even if he has never made tokens for parts of francs such as half francs or centi-francs, he can put them down in his book and add them up to make whole francs as they accumulate in each person's (and his own) written account.

It is worth something to the buyers and sellers to have this convenience and not worry about controlling perceptions related to keeping pieces of paper safe, so even if they must pay Frank's fee, their worth is increased by the value of the convenience Frank offers in trade. Eventually, this bookkeeping service would be replaced by electronic storage and communication between the bank and the sellers and buyers, perhaps using the medium of credit cards to allow Frank to collect his fee. Rather than finding the materials, stamping and engraving or writing proper franc tokens that are hard to forge, Frank now only supplies a safe place to store the data. Furthermore, francs can now be moved from the buyer to the seller without either of them ever visiting Frank's bank in person. Control is made easier for all of them.

If enough people leave their francs in the bank as entries in a book or as data in an electronic file rather than taking them as paper IOUs, there is no reason why Frank should not lend some of them out again in the same way, creating new IOUs that exist only in his records. This is different from Frank producing new francs equivalent in value to the specific IOUs that he burned, but so long as people accept these newly made "electronic francs" as equivalent to the paper francs that were directly exchanged for the old specialized goods-and-services IOUs, they have exactly the same function.

Of course, if too many people come in at the same time and ask for their francs in the form of gold or the tokens he stored for them, and Frank has lent out all his tokens, he will not be able to give them what

is theirs, and people will lose trust in the value of a franc. He is in the same position Tam the barber would be if too many people with her IOUs wanted haircuts at the same time. So Frank is careful to keep enough franc tokens on hand to satisfy the highest number of people he could reasonably expect to all want their tokens at the same time.

Again, collective control comes into play, because the value of a franc is what people can buy with it. If enough sellers think that maybe Frank's bank may not be able to cover all those IOUs when the debt is paid off, they are likely to ask for more francs for their wares, meaning that the value of the franc will be diminished. Again, uncertainty unavoidably leads to inflation, and inflation demands the creation of more money if the total worth of the money in the economy is to stay stable.

If Frank is later proved wrong about the number of francs he must hold in reserve, because too many people want to recover the francs he is keeping for them, the worth of a franc becomes less well defined and its value declines more abruptly. If too many people want to recover the francs Frank is keeping for them, he suffers a run on the bank, the future value of a franc becomes more uncertain, and the public value of the franc declines further. Increased inflation itself adds to the uncertainty of the future value of a franc in a loop that could have positive loop gain more than unity. Inflation "runs away" roughly exponentially (Figure III.8.15).

Ever increasing debt due to a necessary inflation is the price of a stable self-contained economy that does not trade outside its borders. One that does trade across borders can do the equivalent of creating debt by selling more than it buys across the border, thereby requiring the other economy to create compensating debt. Germany did this with much of the world during the so-called "*Wirtschaftwunder*" period after the Second World War.

Excessive inflation, because of which a person may not have a good estimate of the future value of a franc for which she proposes to trade structure, expands the overprice she must ask (Figure q29.5). This, in itself, increases the inflation, and the myriads of such trades daily each have the same effect on the uncertainty everyone would have about the future value of a franc, leading to positive feedback and the kind of exponential decrease in the value of the exchange medium — Frank's francs, dollars, German marks, Turkish lire or what have you — that results in people taking their morning's wages in a wheelbarrow to buy food for the day, because tomorrow that wheelbarrow load of paper might not buy a loaf of bread.

Ignoring excessive inflation, the user of any kind of money still has some uncertainty not only about what a unit of it will trade for in the future, but also about by how muh the trade will change the trader's worth — its subjective value. For both reasons, Frank's francs have an uncertain value to an individual in any one trade (where "value" is a change in the trader's worth, as opposed to a publicly published quantity), but then so does all money. How much can the value of a franc be trusted?

Frank is just one person. He may be perceived as honest, but what if he dies tomorrow? Possibilities like that increase the uncertainty about the reliability of francs, reducing their value in every individual trade. Frank's francs need to be backed not by his personal reputation, but by an institution that survives individual people, such as a Bank with a Board of Governors, or a Government. Such institutions change slower than the individuals involved in their governance, and therefore tend to be more stable, which is a component of trustworthiness. When francs are loaned out by a trusted institution, they become Money. In much of what follows, however, for convenience we continue to talk about Frank rather than an institutional Bank.

Frank has become a bank and is becoming rich (increasing his worth by accumulating fees and interest on loans in the form of francs that he can trade for varieties of goods and services) in the process. His example might be followed by others, each creating their own form of generic IOU. If too many people

did this, the situation would revert to the same confusion of uncertain mutual relative values as was the case with specialized IOUs before Frank created the franc.

With Joe's "joley", Karen's "kran", Penelope's "penny", and many others floating around, the collective control of their relative values would probably be loose, some people perceiving that four krans would be the same as three francs, while other might think five to four was a more reasonable ratio at least for the sorts of things they imagine themselves buying.

When the value becomes uncertain, as was the case for specialized IOUs before Frank invented the franc, and people bargained with different generic IOUs in transactions for the same cut of meat or lawn-mowing job, the values of all the different generic IOUs are reduced. Because a seller is uncertain what a joley will be exchangeable for when he wants to use it, he will ask more than he would have done when he only had to work with francs. The collectively controlled number of joleys required in the bargaining conflict will be increased[42]. When enough sellers do the same, collective control has reduced the value of a joley (and of a franc, a kran and a penny). Inflation is again caused by uncertainty about future value.

There are two ways collective control can address this problem. One is for there to be general agreement that only one of these generic IOU substitutes is an acceptable replacement for the specific IOUs, while the other way is to regulate the issuance of private generic IOUs so that their perceived worths are linked to each other rather than to a basket of specific IOUs.

To allow any single private bank a monopoly on the provision of generic IOUs — which we can now call tokens of "money" — is to unfairly enrich that bank. If there is to be only one source of money tokens, the issuer should be an institution[43] collectively controlled by the community. Typically, but not necessarily, such an issuer is a national treasury. Europe did something similar when it replaced a variety of national currencies with the Euro. The UK took the other path, allowing some private banks in the UK outside England to issue money tokens, with regulations to ensure that the perceived value is the same for all of them (Figure III.8.7).

It may seem odd to accept that a private bank could print money that people would trust and use freely in the real world, but it does happen, both locally and nationally, formally and informally. On Manitoulin Island in Lake Huron (Canada), the local people are called "Haweaters". On the island, "Haweater dollar" coins about the same size as a "Loonie" (official Canadian dollar coin), though silver in colour rather than bronze, were produced for many summers as a tourist curiosity. Stores on the island would accept them and give them out as if they were Loonies, and they could be exchanged for the national currency if tourists did not want to take them home as souvenirs. Electronic Bitcoins are the same. Their value to a person is what that person believes they will buy when they are needed.

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42. Remember that in conflicted collective control, the controlled CCEV will usually have an apparent reference value between the reference value of the two controllers proportionately to their gains, which here we presume to be equal, though later we will not, because the gain of a Giant Virtual Controller such as a retail business is much greater than that of an individual purchaser. The business GVC can set the price for whatever it sells, uninfluenced by the relatively weak loop gain of the purchaser. The purchaser may, of course, go to a different retailer if there is one selling what is wanted at a better price, but that is a different point.

43. "Unfairly" and "should" are subjective terms of approval and disapproval. The concept of "fairness" is addressed in Section III.8.2, while "should" implies that reorganization in the members of a collective controller will probably lead to this result. "Should" is not used here in an ethically loaded way.

The transfer of a bitcoin from one account to another is as good as formal money if both parties can be assured that it is properly recorded for that transaction and for all other transaction, and that new bitcoins are introduced to the economy only under well defined conditions. If that trust does not exist, however, the on-line-only money easily becomes as worthless as a Confederate dollar, and for the same reason. When, however, other forms of cryptocurrency are introduced, the same situation arises as it did when Frank's francs were supplemented by "joleys", "krans", and "pennies". Uncertainty as to their relative values in future transactions reduces their worth now, causing further inflation or the collapse of the different currencies in favour of an alternative, whether that be gold bars, a formal national currency, or something else. The question of trust is a major reason the apparently secure "blockchain" technology is so intimately linked to cryptocurrencies.

III.10.4 Forms of Money

Ordinary money is often transferred in the form of a written IOU, like Fred's francs. Here (Figure III.8.7) are a few such IOUs that are (or were) usable in trades in Scotland and Northern Ireland, and often in England near the border. The English five pound note is usable throughout the United Kingdom. Apart from the Bank of England note, these IOUs are written by commercial banks, in English Pounds.

Figure III.8.7 Varieties of Pound IOUs issued by various British Banks. They all. including the Bank of England five pound note, carry the words "I promise to pay the bearer on demand the sum of .. pounds" with slight variations.

Money need not, however, be conveyed by physical tokens like these banknotes. As a kind of entity that could be traded for the product of work/energy, money is not perceptible to the senses. In a trade, the physical IOU conveys money from one partner to the other, but is not itself money.

Electronic records are at least as good as paper IOUs, to the extent that people perceive their values similarly in trades. A note securely e-mailed by Joe to banker Frank saying that he has transferred 20 francs to Sam's account has the same effect as a piece of paper that says Frank owes Sam the 20 francs he used to owe to Joe, so long as Fred, Joe, and Sam all record the change of ownership.

Electronic transfer records are not the only electronic means of conveying money between owners. Money in francs can be converted into other kinds of denomination such as a cryptocurrency like bitcoin, or shares in a publicly traded company on the stock market.

Why would somebody do that? Perhaps because they expect the public value in terms of work/energy product of the stock or the other kind of currency relative to that of francs to increase. A trade can always be fairly made with someone who has the opposite opinion. With enough different types of cryptocurrency in circulation, the trustworthiness and hence the public value of any of them becomes difficult for the average trader to determine, just as happened when multiple types of specialized IOU began to circulate.

III.10.8 Money and Uncertainty

We have considered money as an atenfel that allows one to trade for something yet to be determined, in effect as a means of distributing a barter protocol over different partners and over extended time. We have considered it as a means of getting someone to control perceptions that are atenfels for controlling some perception you wish to be controlled. Now we consider it as did Bagno (1955), as a communication medium of capacity affected by various noise sources, a medium that facilitates the production of structure. Whereas Bagno had a purely information-theoretic approach, we consider information flows in control loops to reach the same conclusions.

Bagno made the obvious point that money is useless as a toolo to act directly on the physical environment, but the eventual result of using money is entirely its effect in transforming part of the physical world from an unstructured, high-entropy, state to a structured, lower entropy form. In terms we have used many times earlier in this book, the effect of money is to facilitate the export of entropy from a small part of the Universe to a different and usually larger part of the Universe. As do many others, Bagno divided the world into Producers (creators of structure) and Consumers (users and, as we see, degraders of structure because of the side-effects of its use). Figure III.8.8 shows Bagno's basic flow in two forms, a general abstraction which we recognize to be the form we associate with a control loop, and a form in which the action output is labelled "M", for the money channel.

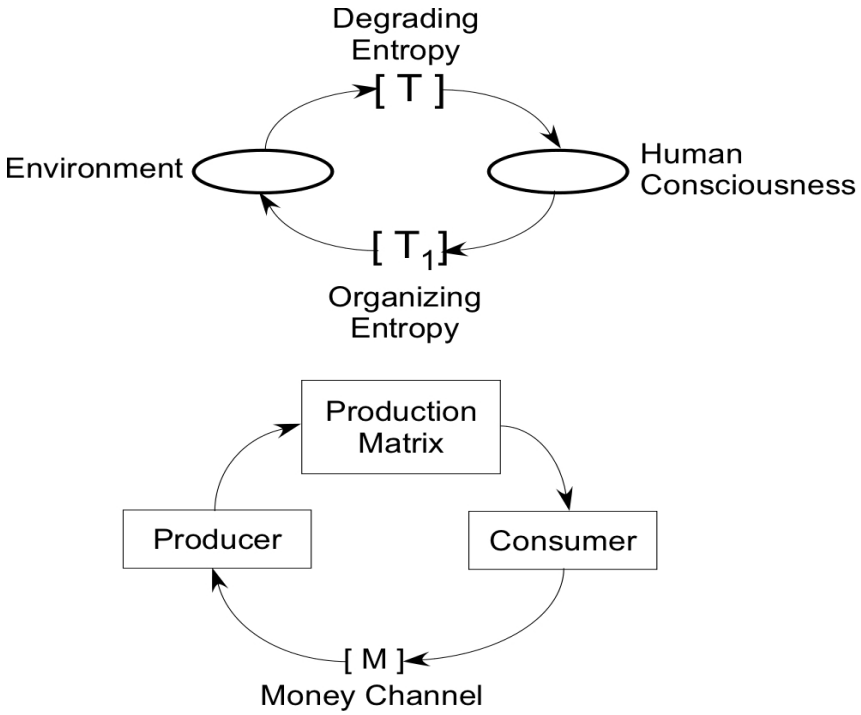

Figure III.8.8 (Upper) The flow of entropy between human and environment, and (Lower) the circular feedback flow around the production-consumption loop using money as a communication channel. (Figure redrawn after Figure 1a and 1b of Bagno (1955))

In Chapter 12 we showed how control is the export of entropy from the CEV of a controlled perception to the environment, or put another way, the minimization of the mutual uncertainty (the transmission of information) between reference and CEV. Bagno shows this entropy extraction as a positive "organizing" process, rather than showing the entropy flow itself. But this "Organizing Process" is exactly what control does, in bringing the value of the CEV and thus the perception to a reference value. Although the controller may see only a value, no matter how complex the perceptual function may be, nevertheless, the essential function of control is the extraction of entropy and the production of structure in the environment.

From a PCT viewpoint, Bagno's reduction of entropy in the environment is perhaps more properly described as a reduction in the entropy of a system consisting of three variables, the reference, the perception, and the CEV, which, with perfect control, would have values of which any two could be perfectly predicted from the remaining one. With no control, the entropy of this system would be that of the reference plus the entropy of the perception-CEV subsystem. The entropy of the perception-CEV subsystem is a measure of the accuracy of perception, since entropy, like Uncertainty and Variance, is additive when the relevant variables are unrelated.The Bagno diagram in the upper part of Figure III.8.8 shows a loop of entropy flow as though everything was additive, which is diagrammatically a little misleading, though it suffices for his later argument. It is misleading because what the "human consciousness" (output uncertainty in PCT terms) supplies is specifically not unrelated to the "degrading entropy" (disturbance uncertainty) supplied by the environment. Indeed, ideally it would be perfectly

opposed to the disturbance, so that the the CEV remained unvarying and the mutual uncertainty between disturbance and output became zero:

M(disturbance|output) = U(disturbance) - I(disturbance|output) = 0

Although mathematically the two uncertainties are positive, the net effect is as though the "Organizing Entropy" were negative, balancing out the "Disorganizing entropy".

What, then, do we make of the lower diagram of Figure III.8.8? It looks as though it is a direct analogue of the upper diagram, but it is not. The "Producer" (the composite of all who make things or provide services including maintenance services) implements the upper diagram, creating structure, reducing entropy. The Consumer, by using the product or service, increases the entropy of the structures produced by the Producer, but by choosing what and how much to buy, passes to the Producer exactly the information required to produce the structure the Consumer wants.

In this, we see the Consumer in two distinct roles, as what Bagno's upper diagram calls "Human Consciousness" controlling the perception of what structure to receive, and as what it would call "Environment", the environment of the Producer that destroys structure the Producer must reconstruct. The two roles of the Consumer interact, in that the "Human Consciousness" Role, which we will call the "Buyer" Role, must acquire the structure before the "Environment" (User) Role can degrade it. The three roles, Producer, Consumer as Buyer, and Consumer as User, form a homeostatic loop (Figure III.8.9), in which Money provides one of the three links. The form of the structure facilitated by the transfer of money must be a perception controlled by a person, since other organisms seldom if ever use money[44]. The loop is homeostatic because the entropy-increasing function of the Consumer as Environment is of opposite sign from the other two structure-creating roles.

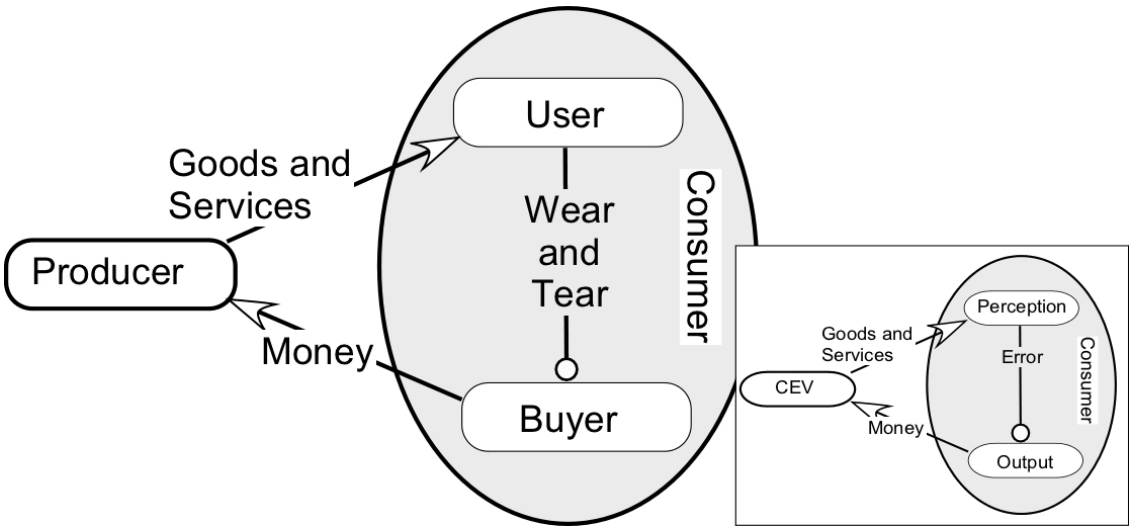

Figure III.8.9 Information flow in a homeostatic loop of production and consumption. The Producer creates structure, the User degrades it, and the Buyer informs the Producer what structure to produce. (Inset) The homeostatic loop shown as a control loop.

44. . Other than perhaps in experimental interactions with people, which we can ignore because the PCT analysis is unchanged if we include them

As Bagno pointed out, for this structure to be in a steady state, the Producer must send to the User structure at exactly the rate at which the User degrades it, and that rate must be exactly the rate at which the Buyer, using the money channel, provides information to the Producer about what structure to produce. The Producer, in turn, acts as a control loop in which the controlled perception is the design of a product, the product is the CEV, and the "disturbance" is the availability of raw materials at higher entropy than the structured product (Figure III.8.10). The whole now produces a network rather than a homeostatic loop, though the network looks like a perceptual control hierarchy with the Consumer acting as a higher level controller using the Producer as the interface to the material environment.

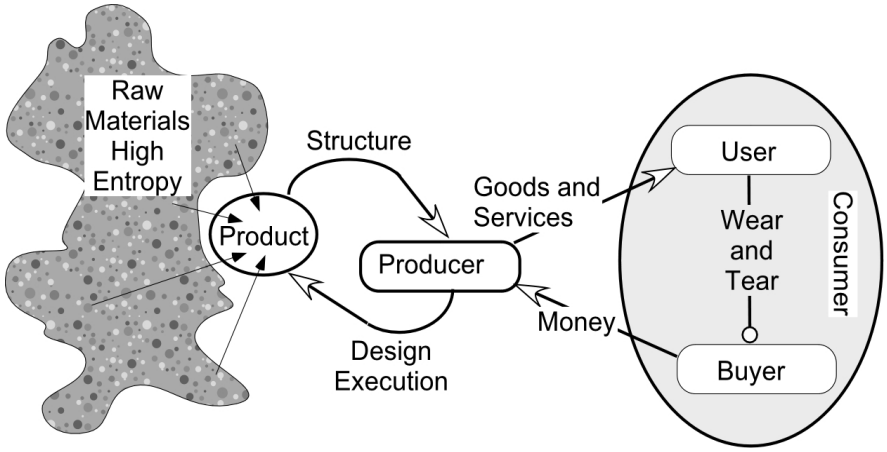

Figure III.8.10 Extending the homeostatic loop by adding the Producer's function as an entropy reducer in constructing the structured product from the high entropy raw materials. The reference design is provided by the consumer in the form of purchasing choices.

In Figure III.8.8, the Producer is linked to the consumer by a box labelled "Production Matrix", not the simple "Goods and services" of the later Figures. This matters, because the Consumer is not a single entity and the connecting information or structure links are not each a unitary communication channel. Instead, like Powers's "neural bundle" of nerve fibres that transmit a "neural current" rather than individual impulses, there are myriads of consumers who want a variety of different things and different quantities of the same thing. In Chapter 12, we called uncertainties about "what" logon uncertainty and uncertainty about "how much of it" metron uncertainty, and these are the terms Bagno uses in the Figure from which Figure III.8.8 is redrawn.

Now we do as Bagno did, and elaborate somewhat on the statement that the information rate must be the same in each link of the homeostatic loop around Producer and Consumer. The elaboration extends the discussion of inflation in Section III.7.6 and Section III.7.7 by identifying "noise" sources that affect the Goods and Services and the Money links between Producer and Consumer. As Shannon (1949) showed, even in the presence of noise, information can be transmitted cleanly if the transmitter adds some redundancy.

In this context, adding redundancy means increasing the Channel Capacity of the link that limits the information flow around the loop. Almost always, the limiting Channel Capacity is the Money Supply. Sometimes it is the availability of raw materials, sometimes it is the availability of people with the skills to create the structure that consumers are willing to pay for, but these latter limits are relatively rare.

One major source of "noise" in this structure is the uncertainty both consumers and producers, (buyers and sellers), perceive about the future value of a dollar. But there is another, a mismatch between the kind

and amount of structure created by the producers and that wanted by consumers. At one extreme, a producer might create a steel bar milled to a precision of one micron, when what the consumer wanted is something to prop up a window to let in some air. At the other extreme, the consumer might want to measure some item to micron accuracy, but the producer offers a measuring tape with crudely printed centimetre marks. In the first case, the producer creates too much structure, which is fine for the consumer if the cost in money to be paid is very small. In the second, the consumer controls for obtaining structure but has no means of obtaining it with money. This kind of mismatch is logon uncertainty, the producer not creating the structure in the form the consumer wants.

The other kind of mismatch is metron uncertainty, the composite Producer producing the forms of structure wanted by the composite Consumer, but producing more of some things and less of other things than the Consumer wants. From the viewpoint of an individual consumer, it is irrelevant that there is an un-bought surplus of something wanted, but if the item is sometimes in short supply, the consumer is likely to buy more than needed, and save some for a time when it is unavailable again.

The logon-metron "Production Matrix" of Figure III.8.8 is not itself the source of uncertainty. There is another such matrix on the Consumer's link between User and Buyer roles (Figure III.8.9). The User Role incorporates perceptual control of properties of the structure bought by the Buyer Role. Much of the purchased structure consists of the "stabilities" described by McClelland in the passage quoted in the introduction to Chapter II.4:

> *The kinds of activities described as work in everyday language are activities that create stable feedback paths in a shared environment for the benefit of other people. The word is also commonly used to refer to the kinds of activities that maintain these feedback paths in place. Thus, work activities produce some kind of environmental stabilization, the creation of some atenfel, molenfel, or molenex, which can then be used in controlling other perceptions.*

In this, the purchased structure enhances the "worth", the ability to control perceptions, of the person in the User Role. But the loss of money in the trade with the Producer reduces the purchaser's worth as a user.

These stabilities require maintenance, which, as McClelland notes, require work, which, as we elaborated in Chapter xII.1, is an intrinsic aspect of the continued life of any homeostatic loop, including the one illustrated in Bagno's diagrams and in Figure III.8.8. The work, even in a managerial or ideational context, necessarily requires the expenditure of physical energy, something we will discuss further in the next Section.

The logon-metron matrix in the User-Buyer link between Consumer roles in Figure III.8.9 is labelled "Wear and Tear", but it is more than that. It also includes changes in the perceptions the person (as User) actively controls. At the Buyer Role, the output of the matrix consists of a "shopping list" that contains the structural forms required to fill the User's needs. It is the mismatch between the input side of that matrix and the output side of the "Production Matrix" of Figure III.8.8 that introduces the uncertainty. In plain language, the composite Producer produces more of some things that the composite Consumer wants, and less of some other things. Informationally, the effective introduced noise is the distribution on average over time of these surpluses and shortfalls.

A "shopping list" is a reference profile for the transfer of Ownership (Section III.3.6) of some structural stability in exchange for some quantity of money. If the Buyer does not have enough money, the information capacity of the money channel for that user is restricted, and not all the information contained

in the reference profile will be communicated. The result of that restriction is that the User is reduced in worth. The person's ability to control will be stabilized at a lower level than they would like.

The noise issue exists also on the money side of the loop. If the Consumer always was guaranteed to have exactly enough money to buy what was needed, there would be no need for savings. These savings of money and stockpiling of goods withdraw structure from the loop, reducing the channel capacities of those links, whether that capacity is measured in bits of structure, in energy used in control, or in money.

These considerations raise the issue of where the consumer in the roles we have discussed gets the money. What we have described so far describes only a one-way flow from Consumer to Producer. We know that money is created from unpaid debt (Section III.8.3), but does this mean that the Consumer must go into debt from the start, and continually increase that debt throughout a lifetime? No it does not, and as we suggested in Section III.8.4, the money is most often created by the Government going into debt. So something is wrong or incomplete.

One missing element is that we have left out an important Role for the Consumer person. If a person is employed, they produce some structure, so they also have a Role in the Producer collective, a Role we can call "Maker". Likewise a person who has a Maker Role also belongs to the Consumer collective and plays both Consumer roles, User and Buyer. The money circulates around roles in different persons and from Maker to Buyer within a person (Figure III.8.11), and is created whenever a debt is created, but is not necessarily destroyed when the debt is repaid.

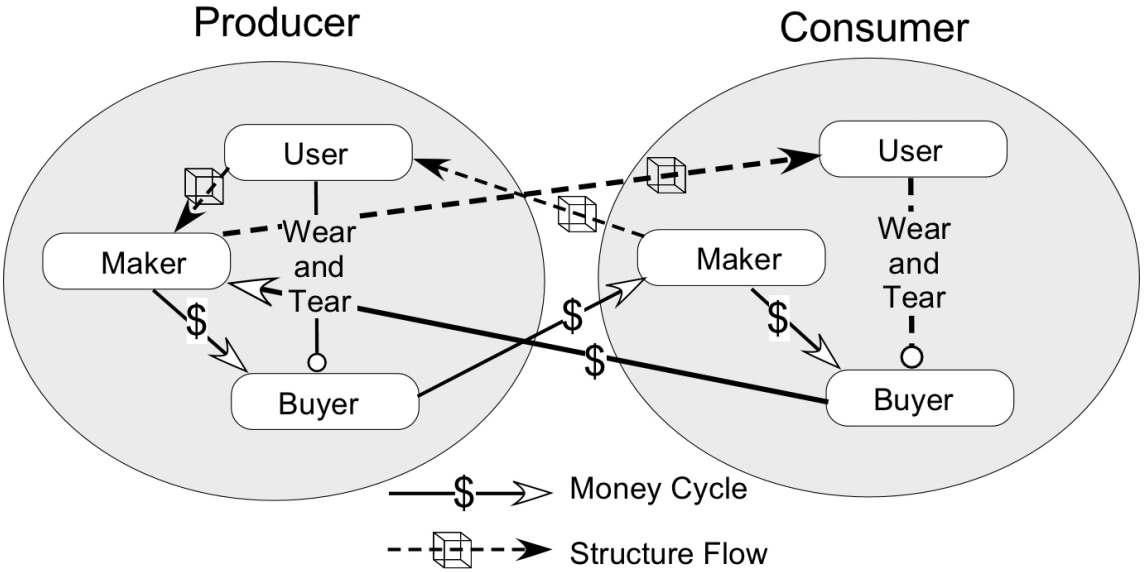

Figure III.8.11 Separating the cycle of money from the production-to-destruction flow of structure between the collective Producer and the collective Consumer, most of whom are employees of the Producer. Here Producer and Consumer are considered as separate persons, but they could be roles within a single person, in which case the money cycle would collapse. We consider the "Consumer" person to be paid by the "Producer" person to create structure that can be sold on to another "Consumer" person. The heavier lines highlight the perceptual control loop of Figure III.8.9. There is a complementary loop of the same form between the Producer and the Consumer as hired Maker.

The structure produced by one Maker may, but usually does not, pass in that form to the User Role within the same person as a DIY product. Even in early times, an expert flint-knapper, in exchange for some benefit, probably made cutting tools and weaponry for other people as well as him- or herself. An important exception to this "usually" is in the person of a home-maker, who more often than not is a "housewife", who creates and maintains structure without payment. Bagno notes that the creation and maintenance of structure by unpaid volunteers has the same sustaining effect on the larger homeostatic network as does the creation of debt by the Government or private borrowers.

In Figure III.8.11, the "User" Role in both Producer and Consumer has inputs and outputs that consist only of structure, whereas the other roles have both forms of connection. They are "translators" in the homeostatic network. The Buyer Role has as inputs the person's reference values for the products required and the money available for buying them. It outputs money that is the information channel to the collective Maker of the products demanded. The Maker Role has as input the information contained in the price offered for the purchase, and as output has structure provided to the other User Role and money as a quantity provided to the Buyer Role.

In this context, it is notable that the earliest civilizations used no money in the form of tokens of defined value. Yet it would be hard to justify a claim that all the structure that was created was done by volunteers. As we described in Section III.9.2, the cross-person link represented by money would be replaced by a structure link representing an offer in a barter trade. Something was traded for something in a way that more often than not gave both partners more worth than they had before the transaction.

The flow of structure could start from an arbitrary state of maximum entropy (zero structure) that we call "raw materials" through a Maker that reduces the entropy of the materials by using energy in the process of controlling perceptions of what the structured product should be. The process of Making almost certainly produces waste material besides the waste heat entropy exported to the environment. At this point in the flow, the non-waste material is at the lowest entropy state it will have, in the sense that the mutual uncertainty between the perception of the structure and a reference value for what was wanted is the lowest it will ever be.

The next notable point in the structure flow is to a User, perhaps by way of many intermediate stages such as storage warehouses, transportation systems and distribution centres, perhaps not, since the User might be in the same person as the Maker, or might be in a person who trades directly with the Maker, perhaps to use that structure as a component in further structure, perhaps as an end User. Let us assume this last possibility.

The structure handed over by the Maker enhances the User's ability to control the totality of his perceptions. It increases her worth, at least as the User perceives it. The mutual uncertainty between the User's reference for what he really wanted and what the Maker produced is greater than that between the Maker's reference for what he wanted to make and the structure that his activities produced (the structure that was handed over). This mismatch is a source of uncertainty, but we can ignore it for now. The important point at the moment is that the User does not maintain the structure against entropic degradation. That is a different Role we might call Maintainer, who is not included in this set of diagrams.

Whether it gets used or not, the structured item, abstract or material, gets old. Using it may cause Wear and Tear (Figure III.8.11), it may lose structure relevant to other potential Users , it may become unfashionable and less useful whether or not it is an abstract Idea or a material object that hardly changes physically. Eventually the owner perceived that keeping it makes some perceptual control more difficult that it would otherwise be, reducing her total worth, and it is discarded on a scrap pile.

The mismatch between the structure the Maker produced and the User's reference value for what was wanted is a more subtle addition to the uncertainty of the barter system. In Section III.9.2 we noted that it

would be nearly impossible for someone to accept in trade an item and expect to get another item in exchange for it that would increase his worth by a precise amount. Thinking of the transmission of structure as information, this uncertainty is noise in the communication channel.

But there is another source of noise in the channel, which we noted above. The Maker produces a structure that conforms (we shall assume) exactly to his reference profile for it. The User also has a profile for what she wants, and she will not accept in trade something that lacks an essential aspect of that, at least not unless she has some way of making good the deficiency. The Maker has produced structure that exceeds the User's requirements in some aspects (for example, he has produced an iridium bar exactly 10 cm ± 1 nm in length, whereas she wanted only a stick or something to prop up a window. Or perhaps the Maker has produced less than what she wants. Both directions of mismatch introduce uncertainty (in the informational representation of structure, it would be called "noise") into the structure transmission channel (Figure III.8.12).

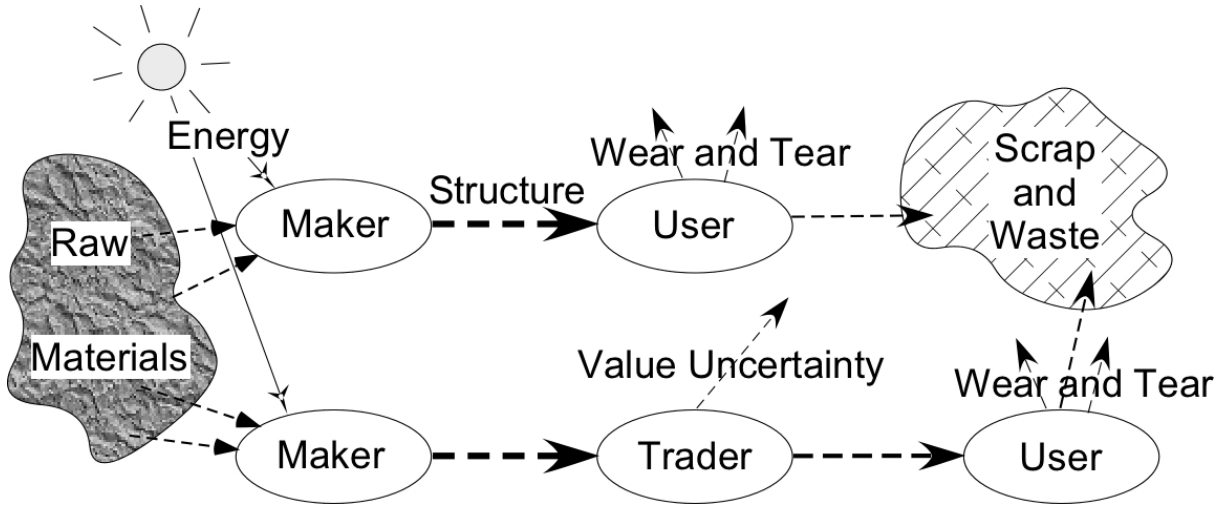

Figure III.8.12 Creation and loss of structure in a barter economy. (Upper) The Maker who creates the structure passes it to the end-User directly. (Lower) The Maker passes the created structure to a Trader, who will later pass it to the end-User in barter for something else.

Perhaps the Consumer was being given a ration of grain by the central authority in exchange for helping with the harvest whose product went to the central warehouse. Grain did not have a a fixed value per kilo in the way that a piece of paper does if it has the proper pictures and has on it wording that specifies its value, like those in Figure III.7.6 or Figure III.8.7. The value of the grain per kilo would fluctuate from season to season on an annual cycle, as well as with the weather and the crop production in the growing season.

Grain, though divisible and transferable, is not money. It is a commodity that in itself allows the owner to control certain perceptions, and is used up in the process. Gold is another sought-after commodity used in early trading, as was silver. Both can be divided, but at the time were useful only to make "pretty things", a use for both that continues to the present day, though perhaps their use in electronics and industrial processes might be more important. A "pretty thing" such as a piece of jewellery or an ornament

on a shelf is itself structure, but in most cases it is not subject to regular “Wear and Tear”, so, as with hoarding and saving, it does not participate in any of the cycles once it has been accepted by an end-user.

In the barter economy, the only way of creating a transaction, a path through the metron-logon Production Matrix of Figure III.8.8, would have been through the use of language. The use of money as the communication medium much eased the creation of that path, as the path from the Producer’s availability input to the User’s requirements could now pass through many different persons, rather than dierectly back to the same person. Bob the Barber no longer needed to wait until Bill the Butcher needed a haircut before he could get a steak to eat, once Bill agreed to accept Bob’s IOUs.

In the language of Information and Uncertainty, the invention of money vastly increased the bandwidth of the trading loop. Money, in that context, was a major catalyst, but the trading economy would continue to exist only so long as people collectively produced structure at least as fast as it was destroyed by neglect, decay, and use. Here we approach the politically thorny problem of “The Commons”, which we will address in the next Chapter.

III.10.5 The Need for Inflation

Bagno (1955) proved the necessity for ever-increasing debt in a closed economy, accompanied by inflation, using an information-theoretic analysis that seems incontrovertible. His analysis is based on an entirely different conceptual foundation, that all public value is the creation or exploitation of structure (discussed above in Chapter 12, and elaborated earlier in this Chapter). We do not use a concept of “public structure”, since we take everything to be the collective product of individual perceptual control. His basic argument, though, is as here, that transactions involve uncertainty about the value of the items involved, and that this uncertainty acts like noise in a communication channel, requiring redundancy in the form of extra money to correct for the noise.

The result is inflation that is required simply for economic stability, though inflation generates its own uncertainty that increases inflation in a positive feedback loop. When the loop gain of the collective control loop exceeds unity the result is an exponential runaway inflation. The economy as a whole gets into situations such as are said to have happened in Germany after World War I, where someone might get a day’s wages in paper notes that were trundled off in a wheelbarrow to be used to buy today’s groceries because tomorrow the wheelbarrow full of paper would be insufficient. When a cup of coffee costs a million (Figure III.8.5), or when a postage stamp costs several billion of whatever the currency unit might be (Figure III.8.6), something is seriously wrong.

Figure III.8.5 A Ten million Lire Turkish banknote I received in change for some transaction. At the time (summer 2000) it would buy ten cups of Turkish coffee.

Figure III.8.6 A German postage stamp for 50 billion Marks at the height of the inflation.

The memory of such events leads bankers to target inflation at rates that are in the long run insufficient to maintain stability in the economy, leading those individuals with the power to do so to try to accumulate wealth (worth) at the expense of the less powerful. Bagno's data suggest that to maintain economic stability the National Debt in a more or less closed economy such as the European Union or the

USA ought to increase by about 2% or 3% of GNP annually, whereas the Maastricht Treaty required the signatory nations to limit their deficit to below 3% of GNP[45].

Inflation may be necessary for the stability of an economy, but inflation is itself a reason why Bill the butcher may be unsure how many francs he will need to offer Tam the barber the next time he want a haircut. If that uncertainty is swamped by all the other sources of uncertainty about the future worth of a franc, it does not cause trouble, though it does fractionally increase the required rate of inflation.

At several points in this just-so story about the evolution of money out of a barter economy, we tangentially noted the need for inflation. In Section III.8.2 we sketched Bagno's (1955) information-theoretic demonstration of the need for steady inflation coupled with constantly increasing total debt. Now we consider the same issue as a consequence of the use of energy for perceptual control. Although we will not belabour the point, we will actually be following Bagno, but seeing his argument from a different viewpoint.

As people use and workers come to accept francs in place of their own specialized IOUs, the total number of francs limits how much total work can be performed at a constant rate in trade for them. The number of francs in circulation is analogous to the diameter of a hose, for which the product of work is the water ejected from the hose. Francs are a language in that they, like language, form a medium through which people communicate to others what they want done. Money is a potential display medium in the protocols that are a necessary basis for the Trade motif.

The total work done may, on the other hand, be limited not by the availability of francs but by the ability of the producers to produce product wanted in trade. If that is the limiting condition, then to produce more francs only reduces the average value in trade of one of them. On the other hand, if it is not, then introducing freshly created francs could increase the total product of work without causing inflation that decreases the value of a franc. And yet, we have argued that for stability we need an ever-increasing number of francs to simply maintain a constant supply of product in good condition.

Do we not have here a contradiction? No, we do not. The reason, as we noted in the initial description of Trade, is the uncertainty about personal value gain from the item to be received as compared with the loss from the item to be given. This mutual transaction gain we originally measured in individual perceived worth, the combined ability of each party individually to control a variety of different perceptions. This uncertainty required each party to the trade to ask for a bit more than what they expect to be the most probable fair trade value. Each person, individually, introduces inflation into every trade, whether or not money changes hands. The perceived most probable value of an item is always lower than the trade value of the item as traded away and higher than that of the same item as offered by the trade partner.

In every fair trade, the worth of each party is perceived by that party as being increased. The total value to the trading pair is increased, no matter that according to a third party observer, each has overvalued what they are giving compared to what they are getting. The public value of the items is the amount of work/energy that is collectively perceived as having been invested in the creation of the two trade items. This perception may not be near the physical truth, but it is the perception that counts.

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45. In my private opinion, Bagno deserved the Nobel Prize in economics, because if his analysis (published in an obscure Proceedings of a meeting of the Institute of Radio Engineers) had been accepted by mainstream economists, we might have been spared the part of the present worldwide "populist" turmoil, due largely to income inequality and governmental deficit-cutting measures.

When Frank managed to stabilize the trade value of a franc in terms of the different specialized IOUs he has been offered or for which he has been asked to search, the range of uncertainty over what could be traded for how many francs was substantially reduced. Items could have a publicly listed asking price in francs. Trading then became specifically buying, usually discarding the bargaining part of the process. The potential buyer needed to assess how much value would be added to his or her worth by the purchase, and whether that value would be greater or less than the lost value of the purchase price in francs. If the item had an expected useful lifetime during which it retained its personal value, the potential changes in the value of a franc over that period might well be included in the expected value of the trade to the buyer.

The seller has a parallel problem, to set the price of the trade item so that when the time comes to use the francs, they will be worth enough in work/energy to more than compensate in value for the item sold now. If the expected change in public value of the franc is slow, the seller has little uncertainty about its value say a year in the future.

The seller expects inflation, but inflation of, say, 3% per annum is easy to take into account if that 3% value is unlikely to change by more than, say, between 2.5% and 3.5%, or over a range of about ⅓ of its current rate. What matters is not the inflation rate but its uncertainty over the time span of interest. If the current inflation rate is, say, 10%, the same proportional uncertainty would lead the expected range a year hence to be between 8.5% and 11.5%. But the actual uncertainty would almost certainly be more, because each increment in uncertainty leads to the seller charging yet more in francs and the buyer to want more work/energy value for a franc.

Earlier, when we were developing the transition of francs from personal IOUs into money, one of the most important stages was the use of debt. This occurred at an individual level as soon as an IOU could serve as a trade item, when Tam offered three haircuts of which Bud could use only one at a time in exchange for a steak. After cutting Bud's hair, Tam is in debt to the extent of two haircuts, and she has no idea who might turn up wanting a haircut in exchange for reducing her total debt by redeeming one IOU. When others followed Tam's lead and offered their own IOUs, the total debt circulating in the community was greatly increased, while at the same time each barter trade was much easier to make.

The next important stage was Frank's introduction of the specialized IOU he called a franc that people could use to pay him for using his time and energy to find IOUs they wanted that could be exchanged for IOUs they held. The franc was indefinitely divisible, which made it easier to find a suitable price in francs for any kind of IOU. As Frank traded more and more francs for his matchmaking service, he could use them in payment not only for his service but also for the proffered IOU, because those traded francs could be used in further trades within the community network. At the same time, the value of a franc in terms of IOUs of different kinds became stabilized by the Law of Large Numbers.

A franc, always, continued to represent a debt owed by Frank to the holder, that could be redeemed by exchanging a proffered quantity of francs for IOUs from Frank's accumulated stash. But notice what is happening here. Frank is collecting the debt accumulated across the community, not all of it, but he owes the debt represented by a franc, whereas the holder of a franc merely uses Frank's debt to trade for goods and services.

The next thing we noticed is the need for a continuous increase in debt in the form of francs to maintain the quality of product against the tendency of entropy to increase. This is additional to the requirement for some added debt to accommodate the uncertainty inherent in every trade. The public value of a franc, and hence the average private value to buyers and sellers, decreases in sync with the degree of entropic decay of product but with the added loss from trade uncertainty.

If Frank does not keep supplying newly made franc IOUs, the community economy will run down. If he does, the value of one franc in terms of work/energy to create structure continually declines —

inflation. It is inflation that keeps the economy stable, and the inflation is supported by an equivalent increase in total numerical debt held by both the public generally and by Frank.

The debt measured in work/energy does not change as a consequence of inflation, because the rate of inflation is measured by how much work/energy a franc can be exchanged for on average. That's for a stable economy. For a growing one, Frank must create more francs, which do not necessarily contribute to inflation since they are traded for added product input to the economy.

The next important stage of this process is that the uncertainty about the future value of a franc has a component due to uncertainty about the stability of Frank's person. To eliminate this source of uncertainty Frank might pass on the accumulated debt to a more stable institution. The community as a Collective Controller has granted this Institution Authority to issue debt that will be accepted in trade in the form of IOUs that do not now say that Frank (who may die) will repay the holder, but that the institution (which will probably not die soon) will repay the holder.

At this point we might note a point that we passed over earlier, which is that the accumulated debt owed by the GVC that authorized the institution is eventually owed to no specific lender such as Frank, but to the Community as a whole despite having been initially borrowed from a specific lender. Furthermore, it is the Community in the form of the authorized debtor/lender institution that owes the debt.

The community owes the debt to itself, but it cannot repay itself because it needs to keep increasing the number of francs in circulation for the creation and maintenance of structure. This just another way of saying that the circulation of debt/money is needed in order to maintain the inflation that keeps the economy stable or growing, rather than gradually fading away. The total debt must continually increase, and unless that debt is distributed finally to individuals and small groups, it must be accumulated by the Community in the form of some institution, be it the Government, a Central Bank or whatever.

The flow of francs is analogous to the flow of blood in the arteries and veins of a living mammal, while the oxygen that flows down the arteries to the working areas of the body is the analogue of the information carried by money to the structure-building working areas of the economy.

Perhaps we can push the blood analogy a little further. Oxygen-carrying blood does not circulate through one big hosepipe from which it is sprayed into the working cells. Rather, it is distributed through a branching structure of ever smaller arteries until it reaches the extremely fine capillary network that delivers the oxygen and returns carbon dioxide to, eventually, the lungs. This is an organization, and we will be following its analogue in the next Section.

In the case of either francs or real money, the early stages of the IOU post-barter economy distribute debt across the working people who create the structures other people want. The information flows at low rates through narrow channels, but by the time the preponderance of debt is owed by a central institution we can call the Government or the Community, the money created by the debt is distributed initially in huge quantities to lesser institutions that redistribute it in smaller and smaller chunks until it reaches those whose work creates and maintains structure. These smaller chunks are themselves organizations within the larger organization that forms the Community as a whole.

One should not stretch this blood flow analogy too far, tempting though it might be. It does, however, point up the fact that it is the *flow* of oxygen and the *flow* of information to where the work is done that are important, not the quantity of blood in the body or the quantity of francs in the economy.

III.10.6 Organization Management

"*Until it reaches those whose work creates and maintains structure*" is rather ambiguous, isn't it? All along, we have been saying that the function of control is the reduction of mutual uncertainty between the reference value and the current value of the perception, which translates into the creation of structure at levels of the control hierarchy below that of the focal perception. If this is so, *every organism* continually creates and maintains structure. That structure, however, exists as seen by the organism's own perceptual hierarchy with input that depends on how the sensors acquire the source data and a perceptual structure that depends on the organism's reorganization history.

How others perceive the direct and side effects of that control on what *they* perceive is a different matter. In most of his writing for publication and in electronic media, Powers considered the side-effects of control by one control loop most likely to serve as a disturbance to the perception controlled by another, and to act independently of any other disturbance. Such a side-effect would automatically increase the difficulty of, and the energy used by, the other in maintaining the structure it had as a reference state.

The same kind of interaction between and among control loops occurs whether within a single hierarchy or in multiple independent hierarchies. Powers demonstrated in his "Arm 2" example (on the CD of LCS III) that reorganization based only on control quality could lead both to non-interference and coordination in a multi-level (14 wide by 3 deep) hierarchy. The apparent conflict with his observation that the effects of controlling against the disturbance to one perception would almost inevitably add to the disturbances to other controlled perception is resolved, since at the beginning of the demo, the hierarchy parameters are random and all controllers do probably interfere with the functioning of all the other controllers.

If unguided reorganization can so greatly improve the control *structure* of an initially randomized hierarchy, so, in principle, could a "supervisor" control system that perceived and acted upon the structural parameters of an interacting group of independent controllers. When all the supervised controller parameters and their interconnections are in individual humans, we call the supervisors of the structure "managers" of an "organization". We will discuss organizations further in Chapter III.9, but here we ask about the amounts of work/energy involved in management, where the structure of the organization is the immediate product.

Earlier, in Chapter III.6, we showed the product as being used directly by the next process in the production of a consumable. This picture must be amended. The structure of an organization as a product is not directly used in any other process. All it does is change the flow of the results of investing work/energy (product) between processes, just as reorganization changes the flow of information among control loops in a single hierarchy. It changes the product or the effectiveness and efficiency of producing the product.

Chapter 12 was dedicated largely to the amount of information required to produce or to perceive a given small well-defined structure, and how that information may be partitioned in resolving a hierarchy of conditional uncertainties Figure 10.13 (reproduced here as Figure III.8.7). The reasoning is offered in Chapter 12.

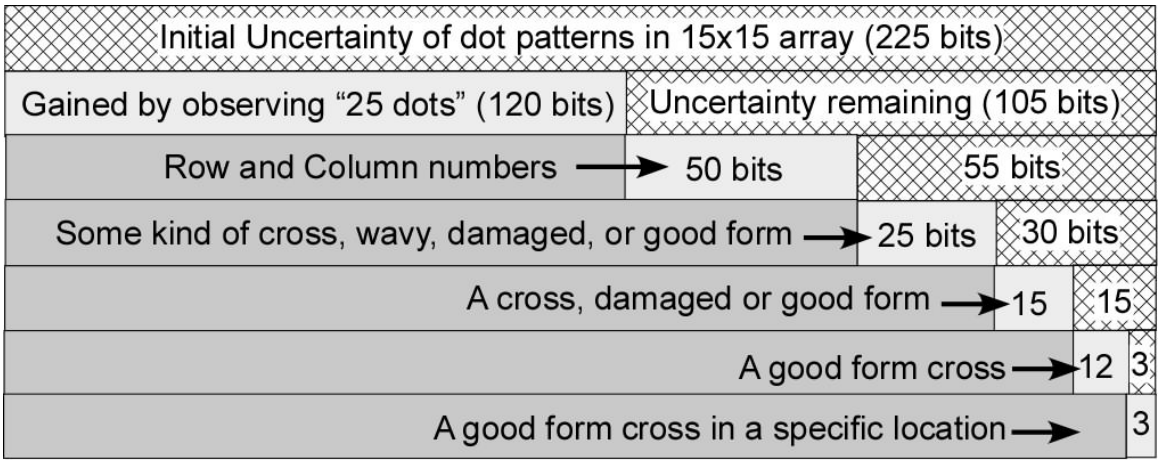

Figure III.8.7 (Figure 10.13 reproduced) Partitioning the uncertainty of a defined pattern within a restricted space of possibility. In this example the space is a 15x15 checkerboard array of squares that may or may not be occupied by a marker. The reference pattern is a symmetrical 25 dot cross (four 6-dot arms about a central dot at a defined location in the space. The figures show the approximate added amount of information (reduction of uncertainty) conveyed by successive observations, given the information already conveyed by knowing the information conveyed at the rows above.

Figure III.8.7 describes a tiny "universe of possibility" (UoP) that we met in Chapter 12. This UoP consists of 15x15 (225 squares) checkerboard, any square of which might or might not contain a marker. The UoP neither produces nor destroys markers, but it can at random move a marker to any unoccupied neighbouring square. Figure 10.10 shows examples of what a "good form" cross structure might look like initially and after one and then another move of random markers, to illustrate the unlikelihood that the second random move restores the original structure. To maintain a good form cross requires maintenance control, which, as McClelland notes in the passage requoted at the beginning of Section III.7.9, requires continual work/energy.

Let us imagine a couple of managerial scenarios. In either, an organizational structure has been constructed. Maybe it was built by the current CEO, maybe not. Either way, this CEO must maintain it in good condition, by appointing the right people to the various roles defined by the structure. That takes a certain amount of work/energy, less if the actual staffing authority is delegated than if this CEO does the selection and appointment alone. Either way, the CEO in this tiny 15x15 universe of possibility controls a perception of the universe that has as reference that the universe is empty of markers except that there is a "good form" cross centred at a specific location. Figure III.8.7 shows that to be a 225-bit construction of the structure of the universe.

In the first scenario, the CEO tells a subordinate "Give me a good form cross with 4 arms of 6 markers each radiating symmetrically from a central point, and I will put it where I want it." From that point on, it is up to the subordinates how they produce the cross for their boss, but produce it they do. They control 222 bits of structure. The good form cross is the product of this organization, and the entire organization executes the "process" in Figure III.8.4.

So it does in the second scenario, in which the CEO "*micromanages*", by setting references for just what some subordinate controllers should produce. In this scenario, two things occur. One is that the CEO's reference setting for the lower levels are likely to conflict with those set by the immediate

subordinates who are charged with giving the CEO a good-form cross. Internal conflicts within the organization impede control overall. The other is that the CEO must use more work/energy in attempting to control those processes that are "officially" delegated to subordinate roles. Does this sound similar to the psychiatric diagnosis of internal conflict that leads to the therapeutic "Method of Levels" (Chapter 6)?

A micromanager clearly uses more work/energy in the production of the organization's product than does a CEO who delegates most of the actual structural information processing to competent subordinates. Since we have been associating money with work/energy in transactions, this would seem at first sight to argue that the micromanager who busily tries to keep the organization working "correctly" should be paid more than the CEO who appears to do nothing because the organization carries on smoothly and efficiently with little action by the CEO. Intuitively, this is wrong, because the micromanager is not helping the organization function as well as does the hands-off CEO who trusts the subordinates to know their jobs. The micromanager's use of work/energy largely creates waste from the organization's viewpoint. The work/energy used by the hands-off CEO does not, at least not to the same degree.

Either kind of CEO needs the organization to produce 225 bits of structure in the product, but the product is not the only structure of interest. The organization itself has structure that must be built and maintained, and this also may be the responsibility of the CEO. From the viewpoint of the Analyst, the process of building and maintaining the structure of the organization is closely analogous to the process of reorganizing a control hierarchy in an individual.

There is a critical difference, however, between individual reorganization and building and maintaining an organization — time. The basic structure in the individual has been evolved through billions of years in which the criterion of quality is strictly the survival of the pattern in descendants. The organizational structure may be based on the structure of previous organizations chosen because they have shown themselves to be successful in some way or other, but that structure has not evolved over even millennia, let alone billions of years.

To build by modifying an existing structure requires less information than to create the same final structure from scratch. Here again there is a significant difference between structuring an organization and reorganizing a single control hierarchy. In the control hierarchy, the basic functional unit is control of a perception produced by a perceptual function.

The same is true of the organization, except that the variable to be controlled is produced by one or more complete control hierarchies that control other variables unrelated to the organization, such as arranging food for the family. Sometimes these other control processes may interfere with control processes within the organizational structure. In a full analysis, one might try to deal with these issues, but as we are talking only about the effectiveness of the organization depending on how much the CEO controls directly and how much through subordinates, these issues can be treated as noise in the information channels.

III.10.7 Money as Infrastructure

We talked in Chapter III.6 about money in the form of tradeable IOUs as a convenience that facilitates transactions that would otherwise have needed trading partners to find goods and services that were worth more to each receiver than they were to the corresponding giver. The possibility of dividing money into very small units, and the ability of the parties to trust what the traded money would be worth in a future transaction were the two keys to the convenience. But so far, other than mentioning some specific goods and services, we have not looked into the other side of a trade facilitated by the one-way passage of money.

Just what is being traded for money? Here we follow Bagno (1955) and argue that what is traded is exactly the work needed to produce and maintain structure. Those words "produce and maintain" refer to the action results of controlling perceptions, in the PCT motif depicted in Figure III.8.4 and surrounding text. As discussed in Chapter 10, the essence of control is the reduction of entropy, the making and maintenance of structure in the local environment. The perceptions of interest are perceptions of the fitness for purpose of the various structures — atenfels — people might use. Some of these structures may be physical, such as roads and bridges, or frying pans and dinner plates, while some might be intangible, such as the functioning of the government structure or the leadership of a sports team, or even of a specialized language when texting.

Back in Chapter 6, we argued that a person's "worth" was in the ability of that person to control many perceptions. "Ability" is not entirely within the person. I would call the part of "ability" inside the person "skill". Ability depends on the person's access to atenfels, together with the requisite skills to use them to control perceptions that the person wants to control. A person does not gain worth by being able to propel a golf ball straight down the fairway if that person has no intention ever to play golf. If this is correct, then the entire worth of an economy is not in money at all, but in its structures. Some of those structures are physical, some social, while many are incorporated in reorganized individual hierarchies and personal World Models.

Education offers students the opportunities to learn the structures (reorganize their control hierarchies and change their World Models) so that they will have the skills to use physical and social structures they may encounter later in life. Any or all of these structures may serve as atenfels for controlling the myriads of perceptions controlled individually and collectively by the people in the economy. Education therefore inherently increases the total worth of an economy.

Bagno claimed that the structures in question are quantifiable. As of 1955, he suggested that the information equivalent of one US cent was 300 bits, which inflation would now have reduced to less than a tenth of that. Let us follow Bagno's argument and see where it leads.

Money is the environmental part of a major infrastructure atenex, for if you have enough of it and the skill to use it you can buy the means of controlling much of what you might want to control, perhaps by hiring skilled help. As we discussed, money must be created and maintained by ever increasing debt and inflation.

Money in itself is not value. Value is what money allows one to do that would be impossible or at least more difficult if one had none. All sorts of proverbs and adages make the point that money can't buy everything that makes for happiness, but it is a good start, and although money is not value, we will argue that it can often be a not too misleading measurable surrogate for a true measure of a person's worth (though not the person's worth to other members of the society).

Ownership of money does not measure the social worth of a struggling artist living in the proverbial garret, who produces much structure in the art without acquiring much money. Artists, starving or not, form a very small part of either the money economy or the structure-production economy, however much we may value their product for the pleasure it gives us or for the money we might gain as investment if we were to buy it now and sell it later. The same applies to many explorers and inventors, most of whom likewise enhance the structural wealth of an economy to a greater extent than is recognized in the money paid them for their work. Nevertheless, both the starving artist and the occasional wealthy Picasso are outliers, and for most purposes to use money as a global measure of worth will be within a tolerable range of the truth.

Infrastructure can be seen as a homeostatically stable network of atenfels and atenexes, all of which enable a member of the society or culture to control variables that would not have been controllable

nearly so easily in their absence. Here, we need only acknowledge that the ability to buy something can obviate the need to learn how to make it and its component parts, and the need to discover and assemble the materials. In other words, one buys structure already created.

Usually, when one talks of a buy-sell transaction, it is said that someone sells goods and services that the other buys. We should examine the background to goods and services. Why should someone buy them if they are perfectly capable of producing them for free? It is sometimes said that "*time is money*", and that is indeed part of the answer, since one cannot act to control all one's perceptions at the same time, but it is only part. The other part is the ability to produce the structure, which involves ability as well as time.

We discussed in Chapters 9 to 12 structure as a set of relationships that reduce the total uncertainty of a set of variables, and have hinted at it many times since, usually in connection with measurements of information and uncertainty. Now we look at it in a less abstract way, and we start by asking what might be structured. In the extended quote from McClelland in the introduction to Volume 2, all of the stabilities he references that require work for their maintenance are structures, whether they be dynamic stabilities like the ticking of a clock or the abstract culturally determined seven-day sequence of the days of the week, or quasi-static material ones such as houses and roads. Construction of a structure requires work, maintenance of a structure requires work, and even the organization of work requires work.

Not all structure requires work performed by control systems to produce it. When one picks up an object from the ground that has not been shaped by human hands or machines, it may well have some structure as we look at it. The structure of a pebble tells volumes to a trained geologist, but the structure is as much in the perceptual functions that the geologist has built through years of training and experience as it is in the pebble.

An untrained eye sees in the pebble a hard thing that might be thrown or used to crack a nut, but not much else. Education has increased the quantity of structure in the geologist's perceptual system, and that structure, too, requires work for its maintenance, not only in the maintenance of the geologist's physical body, but also in his ability to use what he learned in his education and experience, both formal and informal. After a while, when we have not used something we once knew well, such as a foreign language or a mathematical technique, we might say we had become "rusty".

Serendipitous structure, such as that perceived by the geologist in the pebble idly picked up, is not really what we are concerned with here. We recognize that the skill to use a serendipitously discovered structure is itself an aspect of structure, and that the atenfel composed of this skill and the found object may together enhance that person's ability to control in total. This "from education and experience" structure enhances that person's total ability to control — that person's worth. But most structure has to be created by control. Someone generated a reference value for some configuration of materials, and acted on the materials to produce a perception that matched this reference created consciously in imagination.

The appreciated found object contributes something to the total worth of the society, but such found structures are now but a very small part of the total worth of any society that has an effective infrastructure, perhaps as slight as the network of stable relationships among roles in a nomadic hunting party. We are concerned rather with structure created by the exercise of control, by shaping, building, or maintenance. To acquire an object with a structure that is useful for a particular purpose takes work, whether the work is performed by the person who desires that structure or by others. If the work of creating the structure is done by others, the one who acquires it is likely to have done work on something else in order to acquire the money to purchase the desired structure. We see here the beginning of an equivalence between money and structure.

Structure is not only of tangible objects. Relationships among individuals may be structured. One type of sub-network of structured relationships that we have seen many times before and discussed at length in the previous section has a name — a Role — that is instantiated in the person of the individual (or machine) performing it. Roles incorporate, indeed are, learned structure. The structure of a Role such as "Cashier" or Manager" is maintained by a flow of money that is often called "salary" but has many other names that depend on the Role in question. More to the point, the structure is of a particular set of protocols, any of which might be used elsewhere, but define the Role by their co-occurrence pattern.

Structures involving roles tend to be collectively controlled, often as an aspect of the collective control that maintains the structure of an organization within which the Role exists. Structures involving individuals are not. Consider the "cashier" Role. The individual playing the cashier Role may not have any personal relationship with the individual playing the purchaser Role, but the person playing the cashier can perform the Role only by properly using certain protocols, including taking a precise amount of money from the person playing the purchaser. The two persons would not in a random encounter control for transferring money, but the performance of the two roles cannot continue unless the individuals do control for it. In some cultures and situations the roles do not allow the individuals to haggle over the price, but in others the roles almost demand that they do.

Structure, including social structure, allows and is facilitated by the existence of money in a feedback loop. But the argument made by Bagno is that money is a direct measure of structure, and that inevitable measurement errors are the fundamental reason why ever-increasing total debt is essential to a stable (closed) economy. Bagno's viewpoint was entirely based in Shannon's (1949) theory of communication, which we have used in this book under labels such as Uncertainty and Information Theory.

We are arguing now that the same conclusion can be derived from PCT. The work of creating and maintaining structure is the only thing for which money can be traded. Even a donation to charity or a family member creates or maintains structure, if only by virtue of the control of the structure of the donor's self-self-image or other-self-image. That work is control, the reduction of uncertainty of one or more degrees of freedom in the local environment. The degree of freedom concerned may be at any level of the perceptual hierarchy, which correspond to the complexity of perceptions of the corresponding structure property in the environment.

Not all structure is created *de novo* in a trading protocol. Some is, but most is created by putting together smaller structural components into a larger structure, as structured letters can be combined to create more structured words, which can be combined to… and so forth.

Money is far from the only reason people and other organisms do what they do. Structure can be created for reasons that do not include money and can be lumped together as "volunteer work", whether the reasons include control of perceptions relating to curiosity, love, a sense of duty, or whatever. Volunteer work adds to the structure total in the community, and can in some way substitute for money, taking the place of increasing total debt. Indeed, before the invention of money, volunteer work was the only way to increase the total structure of a community, since barter only changed who owned what.

If we now argue that the available structure, rather than the available money, in a community represents its total worth (the abilities of all its members to control perceptual variables), then for an economy to remain stable, that level of structure must be maintained. This doesn't mean that every decaying old house must be renovated to be as good as new, but it does mean that on average the structure lost in the decay and eventual destruction of such old houses should be replaced by other structure of equivalent usefulness in the formation of atenfels. The abilities of the old who die off must be balanced by the abilities of the young who are educated formally or informally so that they can build control structures in their bodies and minds that allow them to use the environmental structures as atenfels.

Volunteer work can to some extent compensate for monetary inflation, but volunteering cannot replace a shrinking value of a fixed supply of money forever, without risking a return to the conditions that existed in the millennia of human coexistence before money was invented. Those conditions depended more on interpersonal interaction than on inter-Role interactions.

Money is an anonymous carrier of structure, unlike the skills of a worker for whose work one might have bartered some item of one's own property or ability. For their existence, roles require the anonymity of the valued medium, whether it be money, tanned hides, or whatever. Roles, such as chief and band member, existed before money, but money helps in their development and maintenance.