# Powers of Perceptual Control:
# An Inquiry into Language, Culture, Power, and Politics

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# Table of Contents


**Table of Contents** .......... **2**
**Preface** .......... **8**
**Part 1: Overview** .......... **14**
**Chapter 1. Why Perceptual Control?** .......... **15**
1.1 Perceptual Control Theory .......... 17
1.2 Control Loops .......... 18
1.3 Measurement and perceptual control .......... 23
1.4 "Deep Learning" "Predictive Coding" and "Enactivism" .......... 27
**Chapter 2. The Environment of Control** .......... **31**
2.1 "Perception" and "Real Reality" .......... 31
2.2 Command versus Control .......... 36
2.3 Atenfels, Contingencies, and Blocks .......... 37
2.4 Viewpoints and the Test for the Controlled Variable (TCV) .......... 41
**Chapter 3. Language and Culture** .......... **44**
3.1 Language and Culture as artifacts .......... 45
3.2 Language drift over time .......... 47
3.3 Culture .......... 50
**Part 2: Simple Perceptual Control** .......... **52**
**Chapter 4. Basic Aspects of Control** .......... **53**
4.1 Perception, control, and reality .......... 53
4.2 The Basic Control Loop .......... 58
4.3 The Output Function .......... 60
4.4 The Reference Input Function .......... 61
4.5 The Comparator Function .......... 63
4.7 Tolerance .......... 67
4.8 Control Stability .......... 71
4.9 Perceptual Complexes .......... 73
4.10 The Control Hierarchy .......... 77
**Chapter 5. Miscellaneous Issues of Control** .......... **81**
5.1 The Behavioural Illusion versus Model fitting .......... 81
5.2 Imagination and the Perceptual World .......... 88
5.3 The Imagination Loop .......... 91
5.4 Exploring and Searching .......... 96
5.5 Planning and World Models .......... 98
5.6 Teaching, Imagination, Learning and Invention .......... 102
5.7 Opportunity, Attention, and Cost .......... 105
5.8 Cost and the perception of "worth" .......... 107
5.9 Avoiding, and the perception of "Not" .......... 110
5.10 Resource Limitation Conflict .......... 113
**Part 3: Interacting Perceptual Controls** .......... **118**
**Chapter 6. Lateral Inhibition** .......... **119**

6.1 Edge Enhancement and Displacement ... 119
6.2 Hebbian-anti-Hebbian (HaH) process ... 124
6.3 Flip-flops and Polyflops ... 128
6.4 The HaH process, e-coli reorganization and Novel Perceptual Functions ... 132
6.5 Labels and Association ... 133
6.6 Analogue and Categorical Hierarchies in Parallel. ... 136
***6.7 Polyflops in the output side of the hierarchy ... 139
**7. Learning: Developing the Control Hierarchy ... 141**
7.1 Reorganization ... 141
7.2 Modularity of Reorganization ... 146
7.3 Misperception and Reorganization ... 152
7.4 "You can't tell what someone is doing …" ... 154
7.5 "The Bomb in the Hierarchy" ... 158
7.6 Control "Stiffness" ... 160
7.7 Tensegrity ... 164
7.8 Tensegrity and the Control Hierarchy I ... 171
**Part 4: Trust, Uncertainty, Tensegrity ... 177**
**Chapter 8. Novelty, Uncertainty, and Illusion ... 178**
8.1 Visual Illusions ... 178
8.2 Effects of Perceptual Experience: Figural after-effects ... 181
8.3 Decisions, Patterns, Habits ... 188
8.4 Trust ... 190
8.5 Belief and Uncertainty ... 192
8.6 Perceiving what's missing or wrong ... 195
8.7 Surprise and belief change ... 198
8.8 Shall I Compare Thee to a Summer's Day? ... 199
8.9 Planning and Performance ... 204
8.10 Consciousness and Emotion ... 206
8.11 Emotion and the "stiff" Personality ... 208
**Chapter 9. Uncertainty and Structure ... 210**
9.1 What is "Information"? ... 210
9.2 Basic Concepts ... 213
9.3 Uncertainty and Perceptual Information ... 218
9.4 Good Form and the Reality of Structure ... 220
9.5 Structure, and Objects in perception ... 223
9.6 The improbability of Structure ... 228
9.7 Fuzzy Nested Macrostates ... 231
9.8 The Universe of Possibility ... 234
9.9 Uncertainty Constraints in Language ... 237
**Chapter 10. Resilience of a Control Hierarchy ... 243**
10.1 Control as cooling ... 243
10.2 The Use of Energy ... 243
10.3 Control as Active Insulation ... 245

10.4 Uncertainty and information around a control loop ..... 247
10.5 Two levels of control ..... 249
10.6 Distribution of effects ..... 251
10.7 Control Tensegrity I: A Small System ..... 253
10.8 Control Tensegrity II: Larger Systems ..... 256
10.9 Control Tensegrity III: Hypernodes and Reorganization ..... 258
**Chapter 11. Collective Control ..... 264**
11.1 Collective Control: Basic Concepts ..... 264
11.2 Stochastic Collective Control: A Gedanken Experiment ..... 265
11.3 Stochastic Collective Control in action ..... 269
11.4 Are Our Own Perceptions Virtual? ..... 270
11.5 The Giant Virtual Controller ..... 274
11.6 A short taxonomy of Collective Control ..... 277
11.7 Tensegrity of Collective Control ..... 279
11.8 Connections ..... 281
**Part 5: Dyads and the Creation of Meaning ..... 285**
**Chapter 12. A Hungry Baby, Side-effects, and Meaning ..... 287**
12.1 Types of interaction ..... 287
12.2 Baby's early interaction: getting someone to feed it ..... 292
12.3 The Generic Protocol Form ..... 295
12.4 Cora and Ivan: Early Development of Meaning ..... 297
12.5 Protocols and Social Perception ..... 299
12.6 Give and Take, Barter and Trade ..... 301
**Chapter 13. A geometric interlude ..... 303**
13.1 The Little Man and the Arm ..... 304
13.2 Syncons and the synx ..... 307
**Chapter 14. Growing up in a culture ..... 309**
14.1 The story of Rob and Len ..... 309
14.2 Baby Len babbling syncons ..... 315
14.3 A language of syncon sequences ..... 316
14.4 The story of Len and Sophie ..... 318
14.5 Len and Sophie have a child ..... 323
14.6 More words for abstract concepts; trajectories in feature space ..... 327
14.7 Higher-level trajectories ..... 334
14.8 Phonetic Symbolism and the Regularization of Verbs ..... 338
14.9 Development and Maintenance of Perceptual Functions ..... 340
**Chapter 15. Protocol operations ..... 343**
15.1 Protocols are for communication, too ..... 344
15.2 The meaning of "Meaning" ..... 344
15.3 Protocol Failure I: Error Correction ..... 348
15.4 Protocol Failure II: Learning to Fix It ..... 349
15.5 Protocol loop dynamical considerations ..... 350
15.6 Multiplexing and Diviplexing ..... 354

15.7 Protocol Identification ... 357
15.8 Protocol as the syntax of interaction ... 358
15.9 Protocol versus Ritual ... 360
15.10 Deceit and camouflage ... 361
**Part 6: Community, People in Larger Groups ... 364**
**Chapter 16. The Fractal Community ... 365**
16.1 Collective Control of Protocol Form ... 365
16.2 Tensegrity and Modular organization ... 366
16.3 Individuals and roles ... 370
16.4 Extending Len and Sophie's family ... 373
16.5 Marcel: a stranger among the Js ... 376
16.6 Modular networks revisited ... 378
**Chapter 17. Conforming to the Community ... 382**
17.1 Roles and Belonging ... 382
17.2 Protocol failure III: Reorganization to the Collective ... 384
17.3 Protocol, ritual, and collective control ... 385
17.4 Rights, Customs, Obligations ... 387
17.5 Morals and Laws ... 392
17.6 Authority and Rules ... 393
**Chapter 18. Cultures and Languages ... 398**
18.1 Cultural Convergence ... 398
18.2 Language: Broadcast versus face-to-face ... 403
18.3 Broadcast language as "Official" ... 406
18.4 Broadcast language: drifts and definitions ... 409
18.5 Cultural Drift ... 412
18.6 Language and Culture as Malleable Artifacts ... 419
**Part 7: Truth, Trust, and Money ... 425**
**Chapter 19. Intangible Artifacts ... 427**
19.1 Artifactual World Models ... 428
19.2 Money as a Collectively Controlled Artifact ... 429
19.3 Money as unpaid debt ... 431
19.4 Banking ... 433
19.5 Ownership ... 440
19.6 Transfer of Ownership ... 441
**Chapter 20. Social Norms, Illusions, and World Models ... 444**
20.1 Trust and Truth ... 444
20.2 Is Truth an Artifact? ... 446
20.3 The Tail of the Invisible Rabbit ... 449
20.4 The Convenient Myth ... 450
20.5 The Stability of Norms ... 453
20.6 The Child's World Model ... 454
20.7 Cultural Norms and Anchors ... 456
20.8 Superstition: The Cultural "Truth" of a World Model ... 459

**Part 8: Organizations, Formal and Informal** ........ **461**
**Chapter 21. Emergence of Organization** ........ **463**
21.1 Infrastructure ........ 463
21.2 Networks of Persons, Roles, and Protocols ........ 466
21.3 Money as Infrastructure ........ 472
21.4 Networks, atenexes and infrastructure ........ 475
21.5 More on atenexes ........ 478
21.6 Invention, the catalyst ........ 480
21.7 Co-reorganization ........ 483
21.8 Side-effect Loops ........ 485
21.9 Loops of Loops ........ 487
21.10 Conflicted Side-effect Loops ........ 493
**Chapter 22. Groups and Organizations** ........ **500**
22.1 The Physical Environment and the Social Environment ........ 501
22.2 Informal Organization ........ 505
22.3 Scheveningen and Shibboleths ........ 508
22.4 It's THEIR Fault: Unfamiliarity, Fear, and Hate ........ 511
22.5 The Big Lie ........ 513
22.6 "The Others" and the Big Lie ........ 515
22.7 Truth Control for Acquiring Power ........ 517
**Chapter 23. Formal Organizations** ........ **519**
23.1 Organizations as control systems ........ 519
23.2 Protocols within Organizations ........ 524
23.3 Trust and Leadership ........ 527
23.4 Teams and team spirit ........ 530
23.5 Teams and Political Parties ........ 532
23.6 Party Factions and Splits ........ 537
**Part 9: Power, Authority, Fairness, and Government** ........ **540**
**Chapter 24. Collective Power** ........ **541**
24.1 Apostasy, defection, betrayal ........ 541
24.2 Defection and Social Control Systems ........ 543
24.3 Power, Individual and Social ........ 544
24.4 Laws and Atenfels ........ 547
24.4 Money, Capital, and Employment ........ 548
24.5 Stock Market, Capital and Unions ........ 549
24.6 Elections and Power ........ 550
24.7 Representation, Coalitions and the Convergence of Power ........ 551
**Chapter 25. Government and Revolution** ........ **553**
25.1 Power imbalance ........ 553
25.2 ***Fairness and the Abuse of Power ........ 555
25.3 The Power of Organizations and triggering the "Social Bomb" ........ 556
25.4 Cultural Reorganization ........ 557
25.5 Cliques are not Teams ........ 559

25.6 **The Great Man ........ 560
25.6 Monarchy and the Ombudsman ........ 560
25.7 ***The Madness of Crowds and the March of Folly ........ 564
25.8 ***Swings of political fortune ........ 564
**Summary of Part 4 ........ 565**
**References ........ 566**
**Acronyms ........ 579**
**Appendices ........ 580**
Appendix 1: General Negative Feedback Loops ........ 580
Appendix 2. Atenfels and Molenfels ........ 584
Appendix 3. A proposed notation for control loops and protocols ........ 587
Appendix 4: The Bomb in the hierarchy ........ 590
Appendix 5: Separations of items in spaces of high dimensionality ........ 593
Appendix 6. Population probabilities of long side-effect loops ........ 595
Appendix 7. Nodes and arcs in the General Protocol Grammar ........ 597
Appendix X1. Information, Measurement, and Control ........ 608
Appendix x2: Probability, Uncertainty, and Fuzzy Logic ........ 622
Appendix x3: The Giant Virtual Controller ........ 623
Appendix X4. Ocular microtremor ........ 625
Appendix X5 Structural microstates ........ 626
Appendix X6. Tensegrity and entropy ........ 635
Appendix x7. Information relations in a control loop ........ 635
A6.1 Basic concepts for analysis of uncertainty and information. ........ 635
A6.2 The Control Loop ........ 638
A6.2 Uncertainty and Information relationships ........ 640
Appendix X8 Network Uncertainties ........ 641
Appendix X9. A possible way to do a simple reorganization ........ 643
Appendix X10 Describing data with several degrees of freedom ........ 645

## 21.7 Co-reorganization

In the passage quoted in Section 21.1, 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. We must look elsewhere for indications that levels of authority and distribution of skills 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, 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 the 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 each 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. Orangutan 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 perceptions they could not control individually.

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, rather than to avoid causing detrimental side effects to others. However, Powers in his "Arm 2" Demonstration in LCS III (Powers, 2008) showed how 14 independent control units reorganized to control different aspects of a 14-degree-of-freedom arm model, starting from an initial condition in which each control unit is connected with random weight to every degree of freedom in the arm in the same way that each of Len's "language-supporting" outputs initially was connected to all his synx features. (A degree of freedom in the arm is an independent joint angle, such as wrist rotation, elbow flexion, and so forth). Powers starts the reorganization with completely random side-effect interferences among the 14 control systems, and by e-coli reorganization arrives at a situation in which the individual ECUs control their particular perceptions with very little side-effect interference.

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 points, obstructions, and nonlinearities characteristic of the world in which we live. Without their implied limits that create the tensegrity "rods" 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 that some build 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 21.1). 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.

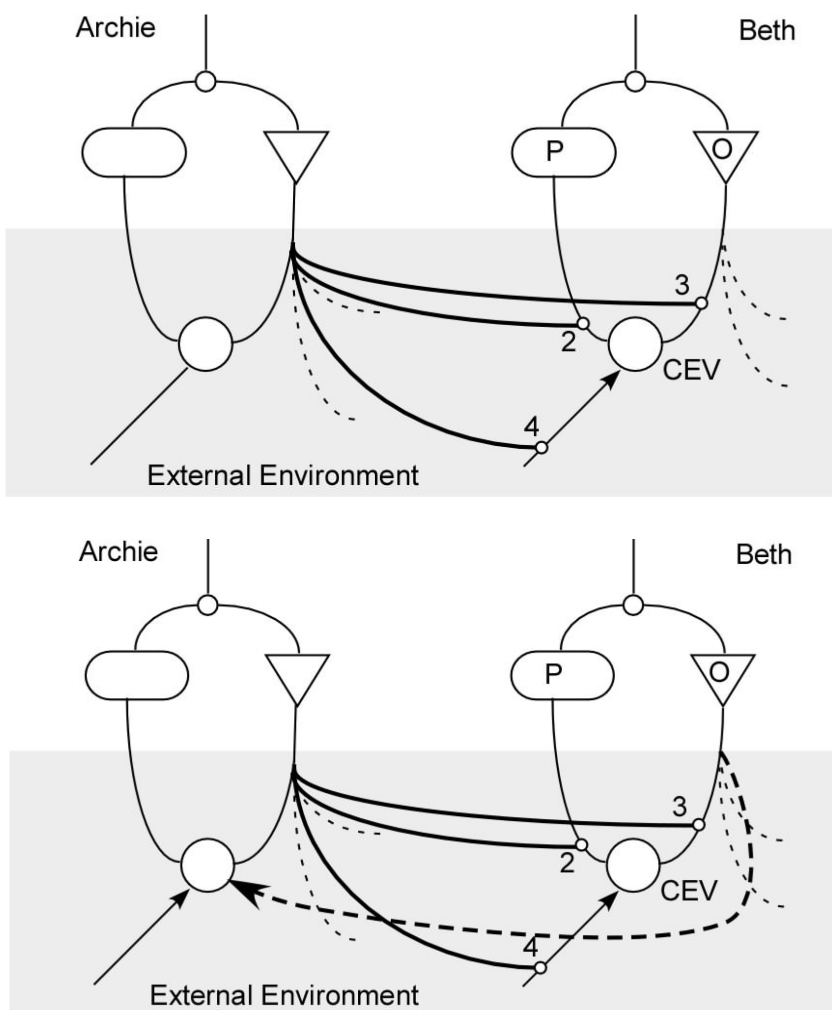

*Figure 21.1. (a, above) Figure 12.2 eliminating path 1, to show only ways the side-effects of the actions of Archie's control system might influence Beth's ability to control, excluding direct disturbance to Beth's CEV. Dashed arcs suggest that the side effects may influence many other people; (b, below) Beth's easier control is likely to reduce any side-effect, including any side-effect disturbance to Archie's CEV, thus easing Archie's control.*

## 21.8 Side-effect Loops

Next, without yet invoking the probable development of protocols that we discussed in Chapter 12, 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 process[111] 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 social groups that 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, as we discuss below (Section 21.9).

It is probably true that most side-effect interactions are simply disturbances to other CEVs (path 1 of Figure 12.2), 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 21.1. We might call this "being inadvertently helpful".

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 the individuals will tend to reduce the incidence of deleterious side-effects. 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 small artificial 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-

111. An autocatalytic process is a form of positive feedback loop in which a catalyst increases the rate of some reaction that produces a product that acts as a catalyst for another reaction, and this continues until one of the produced catalysts increases the rate of the reaction that produces the first catalyst. The reaction rates around the loop are eventually limited only by the availability of the resources that are converted in the various reactions.

effect on Archie's control, so the dashed arc in the lower panel is not directly involved. But it might be effective indirectly.

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 the Charlene wants Beth to help with has 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 rain-proof 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 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 21.2 suggests such a loop, which the beneficent influences occur through a variety of the pathways of Figure 21.1, none of which involve path 1, reduction of any direct side-effect disturbance to another's CEV.

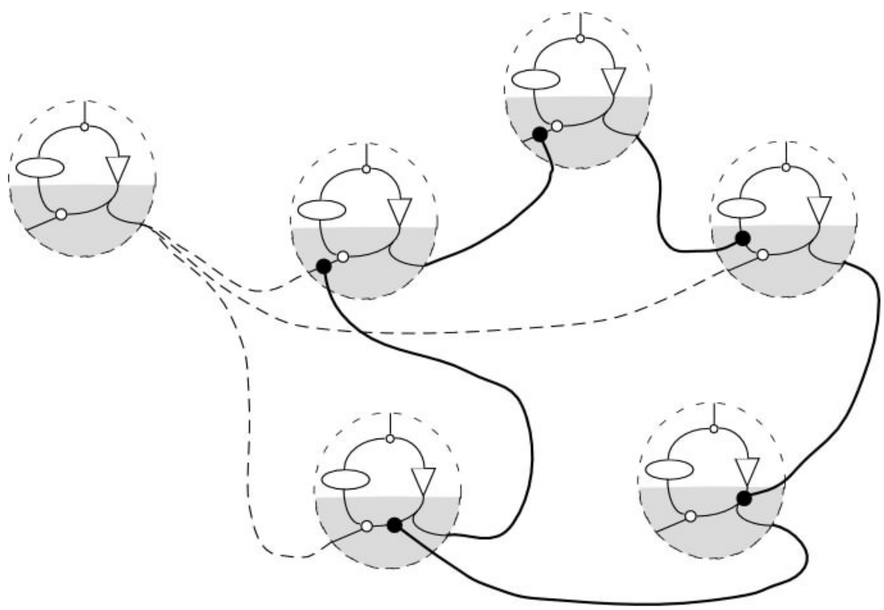

*Figure 21.2 A loop in which 5 control units each have a side effect that benefits another's control, so that around the loop the first one eventually benefits from the side effects of its own control. Some of the 5 are disturbed by the side effects of control by a unit outside the loop. The side-effect 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. We show below that 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.

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 who benefits from belonging to one or more loops probably will not be able to perceive the 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 the control that it benefits. The other might be perceived as a person or as a role — a shopkeeper, a road-worker, a bank teller, or whatever — but if their actions are helpful, the person 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 in the opposite direction that 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. Any one member of a loop may not be able to perceive the loop as a loop, but can perceive their influences (or some of their influences) on their neighbours within the loops, and can control those perceptions. Turning the side-effects into the action outputs of 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 the hybrid loop or its evolved state is longer than two stages, the behaviour at this point has all the overtly visible characteristics of altruism. If it 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 protocol.

## 21.9 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 introducing new atenfels that the 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 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?

To address this question, we use some arguments made by Kauffman (1995). If there is a probability P that the side-effects of one specific control system's actions will inadvertently help a randomly selected other, then the probability that it will benefit at least one member of a group of N is $1-(1-P)^{N}$. Since there are N*(N-1) directed pairs of group members, the probability that the actions of at least one of the group will help at least one other is $1-(1-P)^{N*(N-1)}$. To see how rapidly this probability approaches unity, if P is 1/10,000, and there are 80 control units the probability that there is at least one helpful link is 0.5, it is 0.9 if there are 150 units, and over 0.9999 if there are 300 units.

The chances are greatly increased if we remember that any one person controls a multitude of perceptions, and that the analysis above treats each one individually. But for the purposes of the argument, we will suppose that we are dealing with only one controlled perception per individual and those perceptions are of unrelated environmental variables.

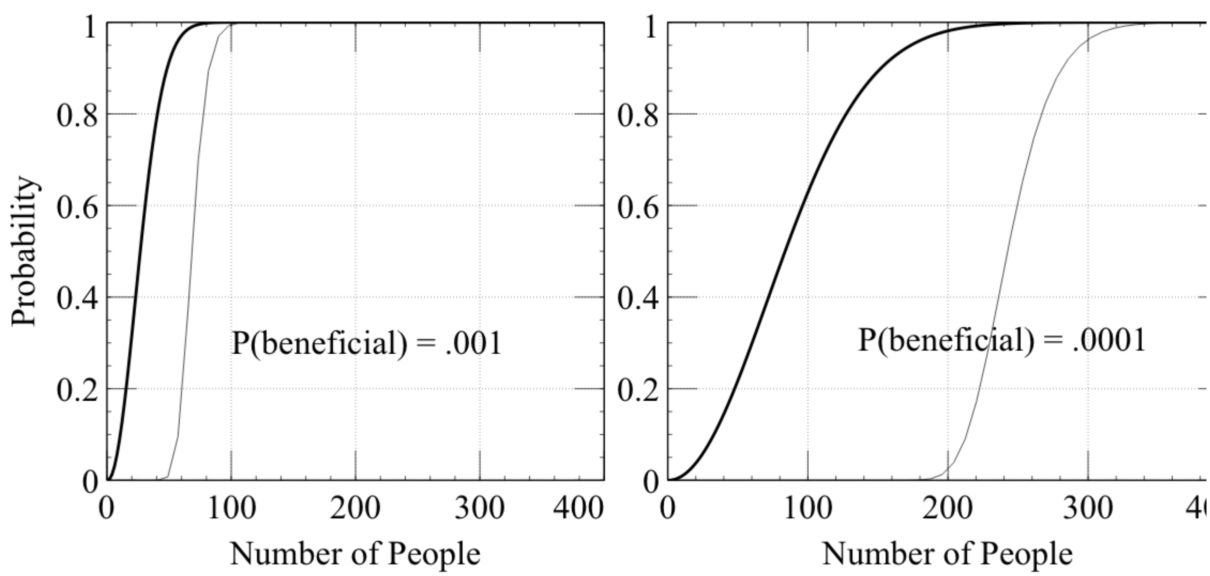


*Figure 21.3. The probability that at least one side-effect interaction will be helpful (heavy curve) and that there will be at least one loop (light curve) in a population of given size, if the probabili that a random specific interaction is helpful is (left) 1/1000 (right)1/10,000.*

When there is a high probability that at least one interaction is inadvertently helpful in a population, there are probably more. The probability that there are at least two, for example, is almost the square of the probability there is one (almost, because one of the N*(N-1) possible interactions has already been shown to be beneficial). The light line in each panel of Figure 21.3 shows the probability that there will be at least as many inadvertently beneficial side-effect interactions as there are control units, for two different probabilities that any one side-effect interaction will be beneficial. When there are as many beneficial interactions as there are people (control units) in the population, it is inevitable that there will be at least one loop in which the side effect of A benefits B, B benefits C, … Z, Z benefits A. So long as A, B, C, …, Z keep acting the same way in controlling their perceptions, they all control better than they would if the loop did not exist.

Figure 21.3 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 350 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 21.3 are worst-case values. The heavy curves assume that interactions occur at random, but 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 than the probability that A talks to a person chosen randomly from the population. Accordingly, the likelihood that several loops exist in the population is actually very much higher than is shown in either panel of Figure 21.3.

What the Figure really shows is that there is a critical group size, probably 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. The density of such loop connections thus marks a "phase transition" in the society akin to the phase transition of materials from a gas of independent but interacting atoms or molecules to a liquid or solid as the temperature decreases. This critical group size may well be at least as responsible for the transition from a nomadic to a sedentary lifestyle as was the invention of agriculture, though 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[112].

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112. Mathematically, the same formal benefactor-beneficiary relation holds between prey and predator. Though the prey is not ordinarily a willing benefactor to the predator, the issue of willingness does not arise because once the prey is caught, its simple presence allows the predator to benefit. Much ecological modelling depends on the existence of predator-prey beneficiary-benefactor loops formally identical to the protocol loops described above, the main difference being that the execution of a protocol between two individuals in different roles does not affect the number of individuals remaining in either role, whereas after a predator-prey interaction, the prey population is reduced by one individual. If, however, we treat the prey as an

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, 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 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 cannot benefit or contribute (or worse, that they contribute but do not benefit, in a structure we might call "colonialism" whether the disadvantaged party is a person or a larger group). We will return to this thought in Chapter 25, on "Government and Revolution".

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 an ECU 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 loops of loops. 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 ECUs.

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. The difference is suggested schematically in Figure 21.4

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anonymous player of a role, ecological network models that ignore population dynamics can be applied to the social dynamics of protocol networks.

Continuing in this vein, a protocol can be abstracted as a directed link in a social network, allowing all the tools of social network analysis to be applied, at least to questions such as the resilience and evolution of network structures.

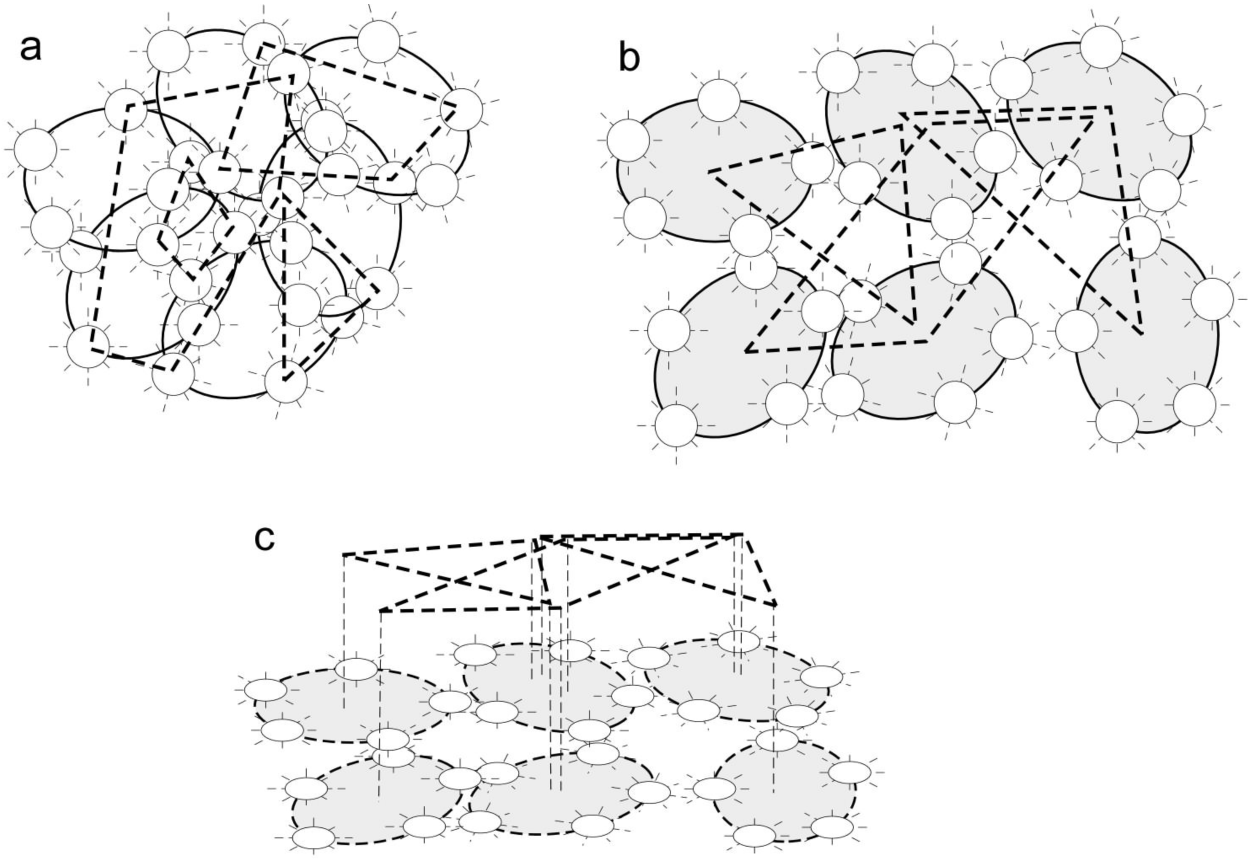


*Figure 21.4 The actions of the individual controllers in a negative feedback loop will have side-effects that affect the control abilities of controllers in other loops. These combined side-effects may also form negative feedback (beneficial) loops. The effects can be visualised in various ways: (a) 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 21.4a 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 21.4b 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.

None of the side-effects of individual actions in these side-effect loops has 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 21.4c.

Figure 21.4c shows the same case as Figure 21.4b, but it emphasises the concept of levels of loops and super-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 21.4 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 21. 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.

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.

## 21.10 Conflicted Side-effect Loops

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, 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 it place in Loop 1 benefits B, forming a Loop 4 (B-Q-Y-C-…-B), as shown in Figure 21.5. The whole set of interconnections will not be nicely discrete loops, but a complex network, in which not everything will be beneficial.

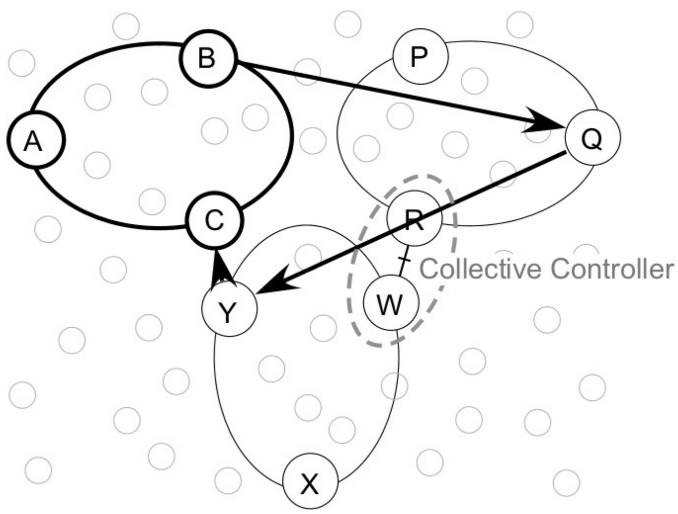


*Figure 21.5 There will be many beneficial side-effect loops involving the same controllers (shown by circles; light grey circles indicate that there are many more controllers than the ones highlighted. If there are beneficial loops ABC, PQR, and WXY, there is no reason B should not also help Q, which 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 21.5 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 21.5 W and R exist in conflict (a path 1,1 loop), both trying to control perceptions of the same CEV at different reference values. 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 activity might actually enhance their individual beneficial side-effects around their respective loops, increasing the negative feedback gain of the loops as well as the escalating 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 in which the side effect of the action of one control unit introduces or alters the effectiveness of an atenfel in the environmental feedback path of the next control unit around the 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 two perceptions of the quantity of each crop, 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 21.6 places that conflict in a situation with two loops, both of which involve Farmer Frank and his conflict.

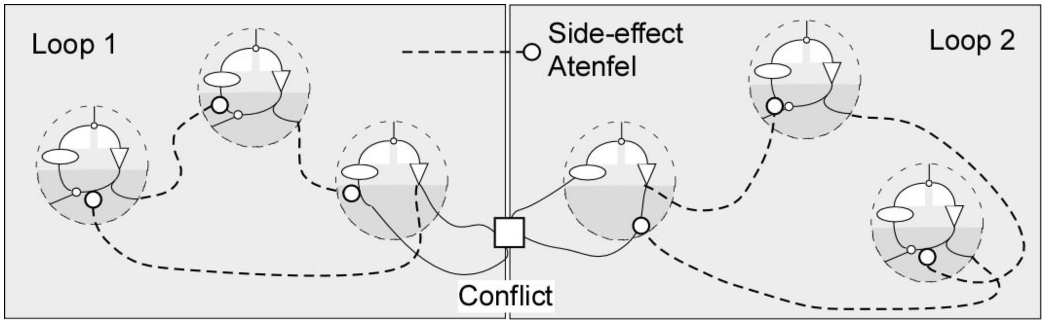


*Figure 21.6 Two loops of beneficial side-effects. In each loop one of the members has a resource conflict with a member of the other loop. The box represents the CCEV over which there is a conflict. That CCEV is stabilized by the collective control created by the conflict.*

The two crops are used by different people — at least we treat 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.

**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. 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. The waste is collected from Helen and composted. Farmer Frank 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 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 21.1.

*Table 21.1 Side-effects of control around the two loops*

| ***Loop*** | ***Person*** | ***Controlled Perception*** | ***Atenfel*** | ***Side-effect*** |
|---|---|---|---|---|
| 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 |
| | | | | |
| 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, he would not need much if any compost, nor would it matter how well his tractor ran, if he had an unlimited supply of volunteer labour.

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.

But these 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.

If Frank grows more biofuel, Steve would get less food and would have to charge more for his limited supply 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, which requires Dan to pay more, reducing his 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 an income from one crop or the other, 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 earlier.

The basic loops in this superficial analysis are not deliberately created by the participants. All the effects, as with the earliest stage of protocol development, are side-effects, 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 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 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 some other controllers, as beneficial atenfels to others, and as creating problems with the environmental feedback loops of others. Figure 21.5 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.

## 21.11 Many people performing a role

The names in this example are applied to single individuals, but they should be considered as not only representative of generic classes, but as representing a large number of individuals of a class. Many different "Helens" may perform the "buy food" 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.

If all the individuals with 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, 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 grow her own food, but this only slightly reduces the side-effect loop gain 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.

Another caveat must be noted. The names in the above represent single control units, 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 (in another control unit) might want to get food from Steve. The interactions of controlled perceptions quickly turns into a complex network or tensegrity structure involving side-effects, direct control, and protocols. In Section 25.5 we return to this issue.