From Runkel
9/86

1 September 1986

Red marks are Hart's, not mine.

Dear Les:

I'm sorry to hear that you are encountering a lot of people--or some, anyway--who do not want to operate their schools in your manner. Naturally, I am not surprised. You have fought your way through all the hard work of figuring out how to do it and of trying it. That makes it easy for you to forget how daunting it must seem to people who don't yet have a glimmering of how to start. Your experience also convinces you, if only because of the investment you have made, that the effort is worth it.

Having so much work behind you of overcoming one obstacle after another, you can now turn your attention to evidence of outcomes, undistracted by a lot of other considerations. New people cannot. They can anticipate great varieties of troubles they would bring upon themselves if they were to adopt your way of doing things. I'll get, some will think, foot-dragging and even resentment from the teachers; they'll say still another outsider is coming around telling them how to run their business. If I undertook this, I'd have to study up on it; I don't have time. Hart says the teachers have to learn the theory; I don't want theory; I want something practical. Yeah, the figures on outcomes look good--in fact, too good; I just don't believe it; no teaching method is that good. Yeah, the figures look good; but there's always a school around someplace that has good figures for a year or two. If it would get around that I'm using "brain theory," I'd have those radical parents down on me before I could turn around; they'd accuse me of messing around in their children's minds. Hart says that discipline problems go away; well, that just shows that he has an expecially easy school here to deal with; I've tried all kinds of things, and _my_ discipline problems don't go away. And so on.

I quite understand that you are very busy doing things and also very busy in your mind checking how your brain theory is matching up with what you are doing. I understand that it is not a good time for me to be pressing a new batch of ideas (Powers's) on you. So I won't.

I'll say only a couple of sentences. Certainly we carry on great parts of our behavior with the help of ~~prosters~~ and programs. But how can they work? If the brain simply set off a rigid sequence of actions, the behavior would frequently fail to bring ~~what the~~ person wants--you never carry out exactly the same sequence of muscle movements twice in driving from your house to the grocery store. So the brain must check that the intended purpose is being furthered by the program. It does that through adjusting the signals for action so that the perceptinn of what is happening is what it wants. In other words, the person acts to maintain a perceptual input. Instead of chasing you to the library, I enclose a first draft of some writing by Powers. You can put it at the bottom of your stack of things to read some day.

Phil

"cloud"

Leslie A. Hart

120 Pelham Road, New Rochelle, New York 10805/(914) 632-9029

Something wrong with the date on this letter. He must have meant September 6.

August 6, 1986

PHILIP RUNKEL

Dear Phil:

Thanks for your letter which arrive today. First, would you like to take the marked paragraph and make it into a CUTTING EDGE piece, not over 750 words? "Why School Successes May Be Slow to Spread" or some such title. See also copy from Carnegie Task Force Report.

Should you not find this appealing, how about a piece that explains what OR is and why education is so little aware of it? Would love one or the other within a month if possible.

I'm not really surprised at the resistance, but more at the people in particular who cannot connect their own demands with these answers--or at least need a lot of time. I plod on.

Re Powers: I'm never too busy to consider anything from you; and always welcome anything that might bear on Proster Theory, especially if possibly negative. I've hunted for the book, and will find it one of these days. I was not impressed by extracts you sent, nor by the latest. He seems right on and well informed, but busy beating a dead horse. True, behaviorists still give courses and students have to learn the crap, but only the backward and unsophisticated argue with it in detail--it is dead. I refuse in sessions to waste any time on Skinner, but I seldom get questions any more. I enclose some pages from HOW THE BRAIN WORKS (1975) which show plainly I had only a bit of ridicule left for behaviorism even then. Also see the feedback passages. I can't see why Powers goes to such lengths to advance ideas which are long accepted.

I don't know whether he sees that brain as a fuzzy instrument, which it is, far from a precise digital machine. My "downshifting" goes far to explain why "the signals for action" vary so much. There is no sharp signals, but a mass of thousands of signals, some opposing or diverse, which emerge overall as some physical action. The brain works by comparison, noting differences and similarities, and by approximation, adjusted by feedback. All this is well established.

In fact, one of my biggest problems stems from schools treating students (or trying to) as if they were digital, not fuzzily analog. They find this hard to accept, but fortunately they can apply the idea and see results before they really buy it.

I don't want ~~to~~ be unfair to Powers but as yet I don't see what excites you. I presume there must be something, knowing your clarity.

Best, and more anon. I'm digging out of a deep pile.

11 September 1986

Dear Les:

I'll try to write 750 words for you on OD. (You wrote "OR," but I suppose you meant "OD"--D and R are only a finger's width apart on the keyboard.)

I don't feel eager to write about "Why school successes may be slow to spread." People are comforted by different explanations, they feel inspired to action by different explanations, and so on. And most have their own explanation for their own schools or districts, and I think their own explanations are usually more useful to them than anything I might write for your newsletter.

You invite me, by implication, to say more about Powers. So I will. You said you "welcome anything that might bear on Proster Theory, especially if possibly negative." Well, I'm sorry, as far as I can tell, I don't think Powers will find any crucial flaws in your theory, or vice versa. I do think Powers deals with aspects of behavior to which you give little or no attention.

It may be of course, that you simply have no interest in those other aspects of behavior. And that's all right. There's no rule that says one person has to be fired up over what fires up another. You may be uninterested, as I said in my letter of 1 September, because you are busy with practical applications. Or because you are primarily interested in aspects that can be readily applied to education. Or, as you said in the lower half of page 72 of your 1975 book (included in Exhibit A, attached), you do not want to fuss with a theory "neurologically or electrochemically detailed or elaborate.... On the contrary,... a simplified model has distinct advantages...."

It may be that you and I differ about Powers because my mind is geared more to the academic world than yours. I put value on the results of studies such as the one by Marken enclosed. You probably don't--or at least you probably put less value on that sort of thing than I do. (Exhibit D.)

In your world, you say, reinforcement theory is dead. I have had the same remark from a vice president of the Weyerhaeuser Corporation. But he and I still get advertising on our desks every week from "behaviorist" consultants who offer to tell you how to get people to do what you want them to do by using the proper reinforcement schedules. And most of the "educational psychology" taught in my college is reinforcement theory. And I know schools where teachers wear stop-watches so that they can be precise about their reinforcement schedules. And schools where children are put in dark closets so they won't get reinforcement for misbehavior (that's called "time out"!). I don't think reinforcement theory will be dead in academia for a couple of decades yet, and maybe that's optimistic. And I live in academia.

In his 1973 book, Powers devotes about as much space to reinforcement theory as you do in your 1975 book. There is a larger proportion in other things I have sent you simply because Powers keep running up against people who believe in the power of the stimulus.

One of my specialties is research method. And the metatheory of current methodology in the social sciences is S-O-R, with no feedback in it.

Powers wants to work out a model detailed enough that he can actually build (using a computer) a simulated "creature." Indeed, he has built a small one. It is described in a series of articles in Byte. I enclose a couple of diagrams from one of those articles as Exhibit C.

Have you read about, or did you see on the TV, the artificial or simulated pterosaur that was built under the auspices of the Smithsonian Institution? I thought it a thrilling triumph. A wingspread of about 30 feet, I think. And the poor creature had no tail and had to steer with its big beak! Anyway, its directtion and altitude change could be controlled by radio by humans on the ground, but its immediate choice of exact amounts of change in beak angle, wing-warp, and all that couldn't possibly be done from the ground. By the time the people on the ground saw which way the air currents were tossing the creature, it would be too late to compensate. The creature had sensors in it to tell it about comparative air pressures, speed of air flow over the wing and head and all that, and the quick adjustments to maintain balance, yaw, amount of wing-warp to compensate for air-flow while turning, all that had to be controlled by feedback circuits that automatically kept the right information coming in from the sensors. In your term, the people on the ground supplied the higher-level biases, but the creature had to have built into it lower-level biases to check on the continuous perceptions and produce compensating action as necessary. The pterosaur must have had circuits in it like the circuits diagrammed in Exhibit C.

I think the NASA people must mean the same thing when they talk about a spaceship "locking on" to a planet.

By the way, the pterosaur broke apart and crashed early in its second flight--the public flight held in Wash DC. Poor thing. But it broke apart because of too-weak "bone" structure in its neck--not because of faulty wiring.

Anyway, that's what Powers means by "model."

You said in one of your letters that your theory is based on neurological studies of the brain. Well, so is Powers's. In his 1973 book, if you ever find a copy, you will find a great deal of neurological back-up.

How might you and Powers differ? As I said, I don't think there are any irreconcilable differences, sharp incompatibilities, or oppositions. You or Powers might disagree with that. Anyway, I'll describe here what I think are four differences, though I'll have to mention similarities even to describe the differences.

To make references to your 1975 book easier, I have enclosed some pages from the book as Exhibits A and B.

1. Powers offers ten levels of hierarchical control. In your 1975 book, you spend the greatest space on two: prosters and programs. You also spend a little space there on categories and patterns. In your 1983 book (that was when you sent me the "proof copy") you put equal emphasis in chapters 7 and 8 on detection of patterns. I think the correspondence between the two schemes is like this:

You	Powers
	Intensity
	Sensation
	Configuration
Patterns	Transition
	Relationships
	Categories
Programs	Sequences
Prosters	Programs
	Principles
	System-concepts

So there is one difference, though in comparison to main-line psychology, there is a lot more similarity there than difference.

2. Both you and Powers emphasize <u>purpose</u> in behavior. Comparing Powers 1973 and Hart 1975, however, you put a lot more space on how we are organized to act, and Powers puts a lot more on how we ascertain that we are acting the way we want to act (control of perception). In your 1983 book, with your emphasis on feedback from reality instead of from the teacher, you come a lot closer to Powers.

Again, there is something of a difference, but a lot of similarity, too.

3. Powers insists at every point on the closed feedback loop running both through the neural net and through the environment. He holds onto it like a bull terrier with a bone. Look at the circuits in Exhibit C and the figure 2 in the pages of my writing that I sent you. But then look at your figures 7, 8, 10, and 13 in Exhibit A. In none of those figures can I find the closed feedback loop. It must be implied, but I cannot trace one in the diagram.

At the top of page 76 (Exhibit A), I find a mysterious use of the word "loop." You use the word and the corresponding thing in your diagram to characterize a program (Powers's "sequence"). I've never understood that.

By calling a program (sequence) a loop, you might mean that a program is used until it is no longer needed, and you might want to imply that control of what is going on is then returned to the proster or to some higher-up proster. On the other hand, you might mean that the efficacy of the program is monitored by feedback. Maybe your loop implies feedback.

So there is certainly a difference in emphasis. Indeed, in your previous letter to me, you said that we don't always act to control input, and especially children do not. Powers says always, always, always.

4. Both you and Powers say that we make our own patterns, programs, prosters, principles, and so on out of our experiences. You are a lot more explicit about the value of random input, and you spend a lot more space on the virtues of a rich environment--and, of course, one unordered by the teacher. Your chapters 8 and 17 in the 1983 book are very good on that. That's a difference in emphasis; I think Powers would applaud you.

5. I'll add one more difference, though it is not a difference in writing or theory; it is a difference in direction and application of work, and I've already alluded to it. You want to go immediately to workaday application in schools. Powers wants to improve psychological research. Both of you have very high standards. You insist on measurable outcomes with every teacher who has learned your theory that are far beyond what the average educational researcher is satisfied with. Powers insists on predictability at least as high as that shown in Exhibit D.

There again, a difference and a similarity.

And now, at the risk of boring you, I'll list some silimarities.

1. See Exhibit A, pp. 74-120. You two agree that higher levels in the neural net set biases (your term) or reference signals (his term) that throw switches (your term) or provide weightings (his term) to select muscle action (programs, in your context).

2. See Exhibit A, the paragraph two-thirds down on page 76. You agree that control systems reach into many regions of the brain.

3. See Exhibit A from the bottom of page 79 into page 80. I think Powers will mostly agree with what you say here about interrupting a program, though it does not always produce annoyance or anger. When the dog comes to the log and must change to programs for stepping over it, the change is no doubt usually done unconsciously, with no emotion produced. No?

4. See Exhibit A, pages 83-120. Your "biases" and Powers's "reference signals" seem to me as close to identical as makes no difference. Your explanation at the top of page 87 of choice of program is very similar to what Powers means by weighting in Exhibit C.

5. Exhibit A, bottom of page 87. Here you say that the brain perceives, evaluates, and deals with the situation. And then you say that by situation, you mean what is perceived by the individual. So it seems to me that the correspondence between your concepts and Powers's go something like this:

You	Powers
Perception of situation (Perception of whatever is perceived)	Perceptual input
Evaluating the situation (evaluating the perception)	Comparator compares input perception with reference signal and produces "error" signal
Dealing with situation (acting to alter perception)	Eeror signal sets off action that continues if perceptual input now produces smaller error signal

6. Exhibit A, page 120. The example here implies--in a phrase like "A new perception signal now goes to the evaluation proster"--that action is taken to alter the perceptual input to bring it closer to a bias-setting. That is, the fish is acting to control perception.

7. Exhibit B. You agree that perception is a continuous kind of thing, not pulsing or episodic. And that the "brain's interest is in changes"--error signals. And that choice of action comes from "feedback and constant questioning of the environment."

Driving a car is also one of Powers's favorite examples.

Oh--speaking of random input, I think Exhibit D is a very nice example, in the small, of what we can do with random input.

Well, I hope I have not wearied you.

If you still want to look at Powers's book, I'll send you mine--actually, I have two copies.

I ought to be able to write 750 words in a month. I'll certainly try.

Yours,

Phil R

EXHIBIT A

Full references
for Hart's two
books are in back
of INSIDE AND [redacted]
OUTSIDE.

The Concept of Proster

IN its most elemental terms, Proster Theory sees human behavior as resting on a two-step cycle:

1. Choosing, from an existing repertoire, a program that best seems to fit the observed situation;
2. Putting the program into effect.

Typically, we decide, then act.

If in some instance an individual has only one course of action open (it is not easy to imagine such a case), then the decision would be automatic—but note that having no choice would mean not even between doing something and doing nothing. Automatic, "wired-in" responses are easy to find in lower level animals, and they may also exist in humans. We need not press the point, since obviously the vast bulk of our behavior does involve choice.

It is equally plain that if choice exists, action cannot take place until a choice has been made; and the choice must be made from *available* alternatives. I cannot escape an assailant by jumping into a car and driving off, unless (a) a car is there to use—the situation—and (b) I am able to drive a car—the program.

Suppose that a third party present sees that a car is there and could be used, but that for some reason I do not see it. So far as my behavior is concerned, no car is there, for what I decide to do is dependent on the situation as *I* perceive it; what other observers may see has nothing to do with me. In the same way, my ability to use a car depends only on whether or not I have the skill to operate it—what percentage of those present, or of the population, can operate a car has no bearing. Individual behavior is *individual*, but this appears to be the easiest fact to forget in dealing with or trying to understand human behavior.

At first blush the cycle of choose—act—choose—act may seem too simple to possibly be a base for complex and infinitely varied human behavior. If the first part of this book has served its purpose, however, it should be apparent that selecting from among a variety of alternative actions is precisely what makes a lot of gray matter necessary. To choose the action most appropriate to the situation implies evaluating or at least recognizing the situation and then matching an action to suit—perhaps selecting from several possibly appropriate choices. The evaluation of the situation and the selection of the action both have to be done in the light of the individual's past experience and his construct of the future. None of this can easily be shown to be unique to *human* brain functioning. Yet clearly man has not even a close rival in terms of the variety of situations he deals with, the subtlety of their differences, and the range and complexity of possible actions. As far as we know, no creature has a memory that rivals man's for storage of past experience, and even less for sense of future.

In the discussion that follows we will be building a model of brain operation. It need not be neurologically or electrochemically detailed or elaborate to serve effectively as the basis of a theory of learning and behavior. On the contrary, so long as it remains consistent with a more technical approach, a simplified model has distinct advantages, especially as we seek to apply it in practice. Our application is not brain surgery, nor even any kind of manipulation or exploitation of the brain's operation. Rather, we are seeking insight into how people behave and knowledge of how to reorder schooling so that it ceases to be an assault on normal brain functioning and instead becomes harmonious—releasing rather than inhibiting, helping rather than impeding, rewarding rather than frustrating.

As far as formal education is concerned, it can be sobering and useful to remind ourselves that, most remarkably, man somehow developed clothing, housing, tools, agriculture, pottery, superb art, writing, weapons and tactics, astronomy, and a good deal more long before the first grade was inscribed on the first report card or the first

diploma handed over to give birth to the monster we now know as credentialism. Formal, institutionalized education is a recent and quite dubiously valuable development in man's history. When the human brain developed in response to needs, those needs did not include going to schools, passing examinations, or coping with bureaucracies.

Since the idea of proster is central to the model, let me explain the meaning of this invented term.

First, consider the idea of program. We live surrounded by a great variety of programs in mechanical form. For example, we insert bread in a toaster and push down the handle. This closes a switch to bring current to the heating element. In due course a thermostatic device responds to the heat, actuating a release—the toast pops up, and the current is switched off. This sequence is built into the toaster, and under normal conditions it will repeat hundreds or thousands of times.

A dishwasher has a more complicated program: once started, it rinses, drains, pumps out, goes through more cold water phases, then a series with hot water, and finally dries. Again, the program is built in, and will ordinarily repeat and repeat.

A phonograph record represents a long program that will deliver millions of consecutive bits of information to the stylus, resulting in a certain fixed sequence of sounds being produced by the equipment. Once the record is put on and started, we will get the same sequence of sounds again and again, modified only slightly by wear and conditions.

Program conveys the essential idea of a "frozen" sequence that does not provide for substantial variations. Even if we consider "branching" programs, in which alternative pathways are provided, the alternatives are fixed. (For example, in a certain computer program, normally number A will be bigger than number B, but it could happen that the subtraction called for cannot be made in some cases because B is larger than A. A branch may be provided, instructing the computer how to handle that situation—always, however, in the same way.)

But now consider a jukebox, that usually garish monster, which presents us with a choice of many programs. A large one can by ingenious mechanisms select any one of a hundred records, position it, and play that program. The programs it can choose from in response to instructions form a group with a good many features in common. All provide aural entertainment, by music, voice, or both together. All are in the jukebox presumably because they are suitable for use in the particular setting. Broadly, they serve the same purpose. Yet there may be good reason for a patron to select one rather than another—to hear one that is gay, or romantic, or suited to another mood, or to have music for dancing, and so on.

The jukebox represents a group of programs that are of a kind, all for the same broad purpose, yet offer alternatives because one may be more *appropriate* than others to a particular need at a particular moment. We can conveniently call this arrangement a "program structure"—or still more conveniently, compress that to "proster." As a new word, proster happily will not carry old associations or meanings.

Now observe my dog walking slowly along a path in the woods. Concentrate on the near rear leg. We can readily see a small program played over and over—the paw put forward, pushed back, picked up, put forward again. The other three legs have their programs, and the cerebellum, we know, is coordinating all four. We call this general program "walking." Now the animal begins to trot—the legs move faster and a little differently. In effect, he has put on a new record or shifted gears. I whistle and he runs to me, using quite a different leg action. If I now invite him for a walk, he will caper and gambol—still another shift of gears.

We can say that the dog has a proster for locomotion: a group of programs for the same general purpose from which he can select one to put into effect. This oversimplifies, of course, for we soon note that the dog has prosters at various levels. For example, if he is walking in the path and comes to a small log, he has to lift his front legs higher, and at just the right instant he lifts his back legs higher, too, over the obstacle he no longer can see. Clearly he has a program for getting over obstacles, a variation on his walking program. For the moment we can skip over these complexities while we first develop a basic model. This idea of program and proster is the key to understanding how the brain works, I suggest, and once we picture the human brain as a collection of a vast number of richly interconnected prosters, its functioning becomes enormously easier to comprehend.

For present purposes, we can represent a proster in diagrammatic, simplified terms (see Figure 7). As I forewarned, we are going to look at "thinking" as basically elaborate switching, with neurons being the brain's switches, sending an activating impulse message or not sending one; or, if having an inhibitory role, sending an in-

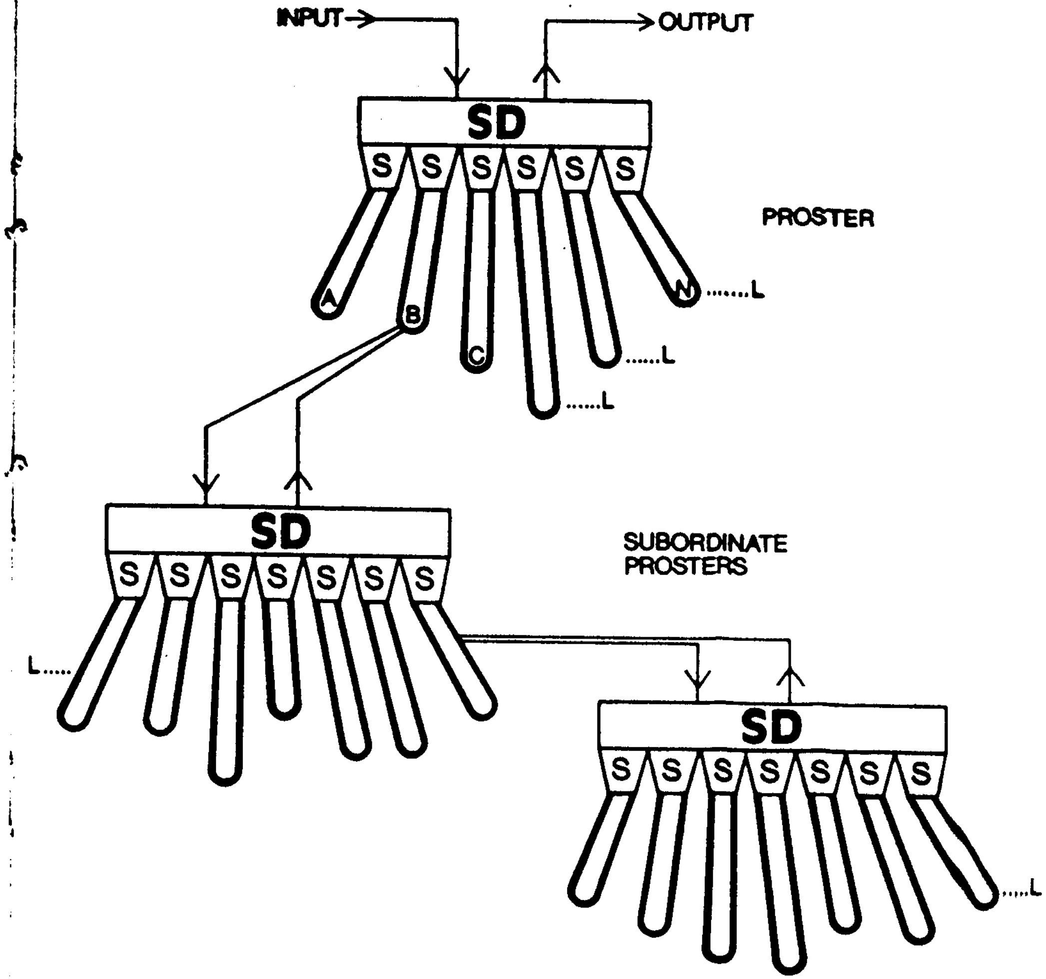

Figure 7

hibitory message or not sending one. (Sending is the switch's "on" position, not sending is "off." The same is true for the great numbers of inhibitory neurons, but here the message sent tends to keep some other neurons from firing.) Despite the complexity of the various kinds of neurons, this binary view appears consistent with present knowledge of the brain, at least for purposes of a general model.

An input signal enters the proster, going into a switching device (SD), within which one of several switches (S)—but only one at a time—can close, thus "playing" one of the attached programs, shown as loops (A, B, C, . . . N). Recall the jukebox, which can play any record in its collection, but only one at a time.

The programs within any one proster are always closely related, but the purposes of the millions of prosters in an adult brain cover a great range. By no means are all the "motor" type, as in this example of my dog's locomotion. Prosters can be seen as serving all the processes of thinking, all the brain's functions.

Programs A, B, C, . . . N may be said to be variations on a theme —or alternative ways of coping or alternative answers to a question. Any program in our initial proster may be linked with one or more subordinate prosters, as indicated for program B. In effect, this means that program B may be varied by cutting in any of the choices in the subordinate proster, which of course could have its own subordinate prosters—ad infinitum.

So far as this main concept is concerned, it does not matter whether the programs composing a proster are long or short, few or many, simple or complex through subordinates. What counts is visualizing the brain not merely as a mass of neurons but as neurons organized into this basic system of prosters, with millions upon millions of prosters having billions of interconnections. In Figure 7 (L) reminds us that all prosters are richly linked with others and most tightly linked with closely related prosters. This relationship, however, can be in many directions; for example, "tree" relates to leaves, green, wood, shade, forest, caterpillars, birds, specific kinds of trees or specific trees, tree as analogy as in family tree or coat tree, and many more.

The proster described is a model, not a localized, physical structure in the brain. It is put forward not as a neurological diagram but purely as a useful concept. What I have labeled "switching device" does express the effect produced by neurons in action. Elaborate gray matter is needed for cross-modal comparisons, such as decision making based on sight-sound, feel-smell, or multisensory inputs. Since different areas of the brain's cortex specialize in handling different sensory inputs, it follows that at least major prosters will *not* be localized, but instead are networks reaching into many regions of the cortex and, in at least some cases, into older gray matter. Prosters then may be thought of not only as the basic thinking apparatus, but also as the networks that, so to speak, tie the brain together.

When designing computers, electronic engineers seek to keep the circuitry as compact as possible, since reduced circuitry has an

effect upon speed of operation. The electrochemical transmission along mammalian nerve fibers is enormously slower, the full range being about from one-half to 120 meters per second.[1] But though tiny "chips" of densely packed electronic circuitry not much larger than a punctuation mark can now be made, the most compact logic devices still don't begin to attain the density of neurons in the brain. The brain compares as an ox-cart to a space vehicle in speed, but compensates in density. And unlike the digital computer, which cannot handle many truly simultaneous inputs, the brain tolerates hundreds of thousands and can carry on a host of intricate simultaneous operations—a stupendous advantage. The kind of search that could be called "prostering" can go on quite rapidly, for practical purposes, because of this simultaneous feature. For analogy, suppose a diamond has fallen out of a ring at a party, and all thirty guests join in hunting for it, each taking a zone. The search proceeds far faster than if one person were doing all the searching, one zone at a time. The brain appears capable of carrying on a huge amount of simultaneous prostering.

Even at this stage, we can see the utility of the proster concept in illuminating human behavior. If we closely observe ourselves or others for a period, we can readily recognize this decide-execute cycle as being what we live by. Throughout the day, we switch on a program and "play" it.

I wake up in bed. I make a choice between rolling over for a little more sleep, lying awake awhile, or getting up. If I get up, I enter the bathroom and activate a complex group of ablution programs. I then must choose what I am going to wear. Having decided on a certain shirt, say, I execute a program involving many steps to open it up, put it on, and button it up. I go through similar choose-execute cycles with trousers and shoes. At breakfast, I choose what to eat and execute the programs for preparing or pouring or buttering, as well as eating. On some mornings I may fix myself either a fried or a boiled egg. Making such a decision early in the morning may not come easily, but the moment the choice has been made the program flows smoothly. In common language I would say if you queried me that "I do not have to think about it," meaning in proster terms that I do not have to "consciously" throw any switches. I merely let the program unwind.

During most of our waking hours we execute intricate programs "without giving thought." Observe a smoker. We see the decision to smoke being made, evidenced by the hand reaching into a pocket

Let me stress the basic tenet of the theory: the brain is organized into prosters, the hierarchy of prosters represents the basic, pervasive mechanism by which the brain works. We perceive, recognize, evaluate, remember, think via level upon level of prosters.

Let us note that this system provides, as does the man-made computer, for branching or programmed alternatives for meeting common conditions. In the instance of the smoker reaching for cigarettes, the hand entering the pocket feels for the pack in the front of the pocket; if it is not found there, the program branches and fingers feel in the back portion; if nothing is found there another branching is cut in and the hand feels in another pocket. These are all pre-set alternatives, within prosters well below the attention level.

But suppose no cigarettes are found. In this case the program has been aborted, and an aborted program typically "sounds an alarm" that instantly brings the problem to attention level. This is a profoundly important mechanism that we shall examine in depth. For the moment consider what happens if you are walking along (executing a locomotion program) when suddenly your foot penetrates what seemed a solid surface, into a hidden hole. No matter what your attention may be on at that moment, the abortion of the walking program will take precedence.

Or suppose you reach for your wallet to pay for a purchase and find the pocket empty. You are likely to feel the effects of a surge of hormones responding to an emergency call—even if in an instant you recall that you deliberately left your wallet in a drawer and have cash in another pocket. In Proster Theory terms we would say that you had a scare not because you thought your wallet was lost or stolen, but because a familiar (and important) program was aborted.

Abortion of a program produces emotion because it is a *threat*; "Something is wrong!" How much emotion is felt, and of what kind, depends on the importance or implications of the program. Suppose I am taking a shower. Following my usual program, I step out and reach for the towel on the rack. But there is no towel there. Instantly I feel annoyance, quite possibly vented with an expletive. The abortion forces the problem to my full attention, driving out whatever I was consciously thinking about. I am now forced to rechoose a program at the attention level. I might call to someone to kindly bring a towel (program B), or go dripping wet to the closet to get one (program C), or raid another rack (program D), or otherwise find a program I can execute.

But now suppose I am not at home, but a first-time guest in a strange house, and my hosts are asleep. Lacking a program, I may find myself at least for a time confused, embarrassed, and immobile—I have no available program, I don't know what to do. The young, I suggest, often seem to older people either stupid or rude because they simply have far fewer established programs in their prosters. Lacking choices, they may appear silly, boorish, careless, or insensitive. Note too that in emergencies such as accidents, fires, explosions, and the like many bystanders often seem rooted to the spot. Either they have no preexisting program that can be executed, or the selection process has been for the moment inhibited. They do nothing; they may be described as frozen in their tracks. Unless they have a program to execute, there is nothing they *can* do but freeze. *No program, no activity*, in spite of tremendous "stimulus."

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In recent years it has become vigorously evident that children can achieve important learning far earlier than traditionally they were thought capable of. Within education, where folklore serves so commonly as respectable wisdom, this has not of course served to dispel entirely notions about children's brains or eyes not being mature enough when they enter school. Should this nonsense somehow be knocked down, many teachers have a fall-back position: the child, they submit, should not be subjected to the pressure of learning. What they really mean, of course, is the pressure of teaching. To learn is precisely as natural and necessary as to breathe. To prevent or hinder a child from learning is the exact equivalent of interfering with his physical growth.

Assuming the inventory of prosters has been acquired, how is the right program selected from the many available?

Consider again the diagram of a single proster, with some additions (Figure 8). Note here the additional inputs to the switching device (SD), a, b, c, . . . n.

Recalling the discussion of homeostats and the term bias, referring to the setting of a homeostat (as we set the household thermostat that controls the heating plant), we can call these side inputs simply biases. These bring signals from elsewhere in the brain, which *in*

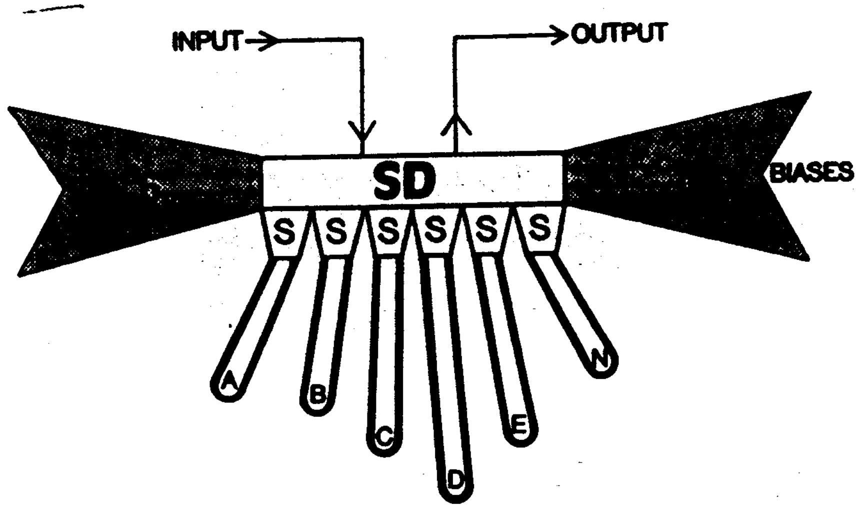

Figure 8

sum influence which of the selector switches (S) in the proster will be activated.

While the analogy of a gun firing illustrates the all-or-none principle, a single discharge by a neuron has no effect. Only its continuing discharge—like that of a machine gun—will have any influence on other neurons. The rapidity or frequency of firing may have significance; and even more, changes in the rate of firing, which, by variations, can produce a pattern.

Numbering in the thousands of billions, synapses have a key role that still eludes precise definition, although much of the mechanism has been resolved in detail. Strong evidence has been accumulated that *graded*—in contrast to all-or-none—effects are produced within the neural network. This may sound contradictory, but for analogy think of a board of directors that has some progressive and some conservative members. Each has only one vote (all-or-none principle), but at various times two, three, four, or five of the progressives may vote together (graded effect). When more votes are cast for action than against it, it will be taken, and when more vote against than for, it will be inhibited.

This well-established basic brain structure suggests that the concept expressed by the proster diagram is substantially consistent with the actualities derived from neurology.

Consider once more the proster diagram (Figure 10).

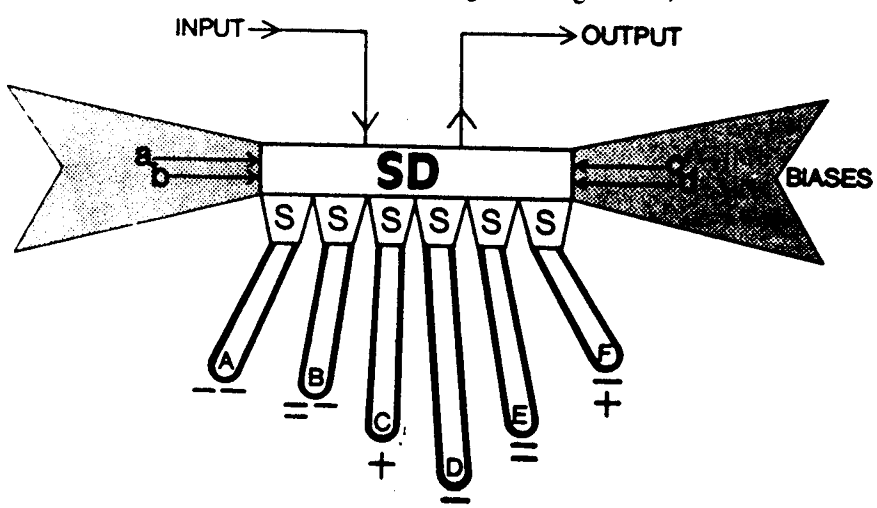

Figure 10

Let us say that in this instance bias (a) is strongly inhibiting the switches for programs (A) and (B), as indicated by double minus symbols (— —). Bias (b) is weakly inhibiting (—) switches for programs (B), (E), (F). Bias (c) is weakly inhibiting switches for programs (D) and (E). Bias (d) is weakly activating (+) for programs (C) and (F). Summing up, we see these totals:

(A) . . . — —
(B) . . . — — —
(C) . . . +
(D) . . . —
(E) . . . — —
(F) . . . 0 (+ and — cancel out)

Under these circumstances, program (C) would be activated. If aborted, program (F) would be the next choice. (If all programs were inhibited by biases, the input to the proster would be refused and shunted out.)

To illustrate, only four bias inputs have been shown. In reality, there could be thousands, so the switching device would produce a far wider, extremely subtle range of values by which one or another program would be selected. For purposes of insight into behavior and fostering of learning, we do not really have to worry about the mechanism, once the concept of hierarchy of prosters is accepted, at least for use as a model.

I have used the word "appropriate" with reference to the choice of a program within a proster. Smith defines it succinctly:

> . . . The world is full of a restless energy: it is full, in Whitehead's phrase, of a constant and unending "stream of happenings." It is the animal's part to respond to these happenings in an appropriate manner: a manner, in short, which ensures the prolongation of its individual life so that its progeny may perpetuate that of the species.[2]

For man, this means ability to survive in a variety of settings, circumstances, and environments much greater than most other animals can tolerate. The uniquely manlike aspects of the brain must relate to unique origins and behaviors.

We can then define the human brain in one basic way as an instrument for perceiving, evaluating, and dealing with the situation in which an individual finds himself.

Let me make a distinction between *setting* and *situation* to avoid some serious confusion. I will use setting to mean a circumstance as it might be observed by various people, and reserve situation to mean only what is perceived by the individual under consideration.

At this point it may be helpful to examine Figure 13 and to trace step by step the processes going on. Let us assume a very early fish-like ancestor with a simple brain. (Even so, much of the circuitry is omitted in the diagram for the sake of clarity.)

The subject creature is already in a situation, since we flow from one situation into the next with no way of ever *not* being in a situation. Assume in this case that the fish is feeding, ingesting small particles of food as it hovers over a weed patch. The many aspects of this whole situation we will simply summarize as circle A.

At B we will deal with just one receptor, an eye—by no means as good an eye as humans have, but far more primitive both in itself and in terms of the recognition prosters it feeds to.

Since the creature has a brain, it is aggressive in probing its environment, which is to say it takes the initiative, and looks as well as sees. The dotted lines (1) represent looking, the solid line (2) the visual input falling on its retina as a result. This input derives from a dark object (C) some distance away and nearer the surface of the water.

From the visual receptor (B) binary-coded signals are routed to a perception proster, as shown by the line (3). Our creature does not have much brain, so its prosters are few and not well stocked with programs. In this instance the best recognition that can be matched is the stored program (4) which tentatively identifies the object as "possible predator."

Now follow the output (5) from this perception proster as it goes to an evaluation or main decision-making proster. Note that this proster has bias inputs from "Situation" A; and so biased, it selects from available alternative general programs the one marked (6) —namely, "leave" the scene because of "possible predator." If the subject creature had not eaten for a long time and was very hungry, the bias input marked "hunger" might have a stronger value and the

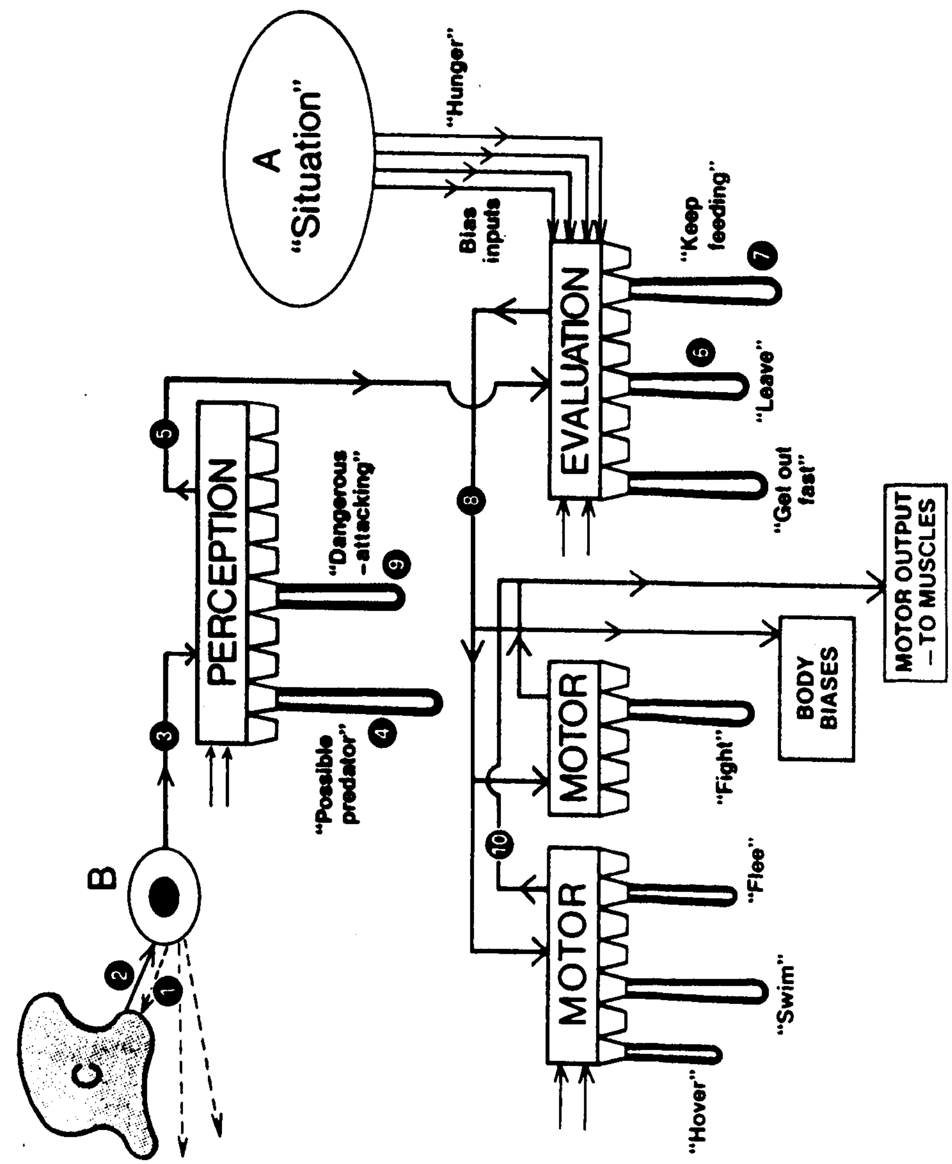

Fig 13

evaluation proster might instead switch on general program (7), be cautious but "keep on feeding." Let us assume that it has fed for awhile and that the "hunger" bias is therefore weak, and so (6) is put into effect.

The output from the evaluation proster, line (8), carries to the motor proster. For simplicity, we will assume here a choice exists of only three programs: "hover" as in feeding, "swim" as in normal locomotion, "flee" as in emergency. Closely linked is a "fight" proster which can be switched on by the higher-level evaluation proster if "flee" is perceived to be inadequate. Most animals will fight as a last resort, whatever the odds, if the circumstances permit. These prosters of course are being biased by many inputs (omitted in the diagram) from the situation as it changes from moment to moment. At this instant, "fight" stays switched off, and "hover" is now switched off and "swim" switched on, thus effecting in motor terms the evaluation decision to leave the scene.

Our subject starts swimming away at normal speed. Where it swims is a choice made by other prosters. But before long the continued radarlike probing and questioning of the environment by the eye results in a new clue being obtained: the behavior and shape of the dark mass is now identified by a recognition program (9) in the perception proster as "dangerous predator attacking."

A new perception signal now goes to the evaluation proster, which makes the decision "get out of here, fast!" New biases now affect the motor proster—"swim" is switched off and program "flee" is selected. Motor output signals are sent (10) to reach the muscles. Our creature now swims away at maximum speed.

But "flee" requires that the body biases that serve well enough for "swim" be reset. Energy must be released faster. Digestion can be stopped temporarily. By linkages too complex to show in this diagram, the housekeeping parts of the brain effect these shifts of body biases.

Let us say our subject is now chased against some rocks so that "flee" is aborted, and for lack of other alternative "fight" is switched on. This calls for further resetting of the body biases, for the animal may as well exhaust itself fighting as die by being eaten. The biases then are set at extremes, using energy at a pace that can be maintained only briefly.

What we mean by emotions (at least within Proster Theory) is this *resetting* of body biases. But such resetting is ordered by the brain; and accordingly the linkages involved in producing the orders cannot meaningfully be separated from the bias shifts themselves. If a judge orders a suspect to be put in jail, and he is, we cannot say sensibly that the judge is responsible for the order but not the jailing, or responsible for the jailing but not the order. Nor can we separate the brain's giving orders to reset body biases and the actual resetting. We may, of course, reset biases for "flee" but then countermand the order to flee; but the fact that we did not use the resetting does not change the fact that the resetting was accomplished. It is the resetting of biases, the preparation for a change in activity, that constitutes emotion. And the emotion involves the human brain at all levels. To oversimplify, the oldest brain does the body resetting, the middle brain gives the orders, and the new brain provides complex and detailed analysis of the situation and gives permission for or inhibits the emotion. But the new brain, the cerebral cortex and its associated pathways, does not always win. It can be temporarily shunted out of the decision making as older, simpler circuits take over. A suitable term for this is "downshifting."

Why and when does downshifting occur?

Again we must remember that the kind of brain we have reflects what happened to our phylogenetic line over hundreds of millions of years. During all but the last tiny fragment of that period, the first necessity of "brain" was that it provide for survival in simple physical terms. In our civilized daily existence, our ability directly to affect our survival has become blurred. The win-or-lose struggle that characterizes so much of nature has been transmuted to infinite gradations and complexities. We no longer live with death, aware that a predator may strike at any moment, that we must take frequent risk of death to gain the food to survive, that the coming of winter raises realistic doubts whether we shall again see the coming of spring. On the contrary, we assume that we shall live to seventy or more. The threats to long life take on an accidental, capricious quality: a heart attack out of the blue, an auto or airplane crash, an explosion, a flood, an earthquake. Or war, subjecting us to the sudden, unseen hazard of the bullet or mine or bomb that finds its mark.

We have little sense of control over these matters. They happen. As with losers at a roulette table, the wrong numbers came up.

Further, survival itself has become less a matter of live-or-die than one of existence graduated along many scales. The electricity fails, our house grows cold, the appliances won't operate, the television stays blank. Events beyond our influence, or even knowledge, have abruptly changed our level of existence. The same shift occurs when we lose employment because of a merger or are injured in an accident, or, in the other direction, are cured of a disease or inherit a fortune. Since we expect to live, *how* we live—by many criteria—becomes our focus, not simply "to be or not to be," which we often can't influence anyway.

But against these new attitudes and needs stands the great bulk of our life history in species terms, in terms of the thread of existence that stretches back half a billion years or longer. During most of these vast periods, the focus was on moment-to-moment and short-term survival. Our reptilian brain is still constructed primarily to meet that need. Our old mammalian brain, though far more elaborate and much more subtle in discerning situation, still operates by essentially the same rules—as it were, a few brief maxims that served at the reptilian stage have become several pages of sentences with "if" and "but" scattered liberally throughout. By comparison, the more recent neocortex is the reference room of a sizable library. It is not the place to go for a quick, simple, time-tested answer. There is too much information, too much variation and qualification, too much that gets in the way of an instantaneous decision on which survival itself may depend.

Two main factors operate here: speed and complexity.

To grasp the importance of the first, we can closely observe some sport—baseball will serve nicely. One appeal of the game no doubt stems from the yes/no simplifications it produces. A pitch is a strike or a ball, nothing between; a runner is either safe or out; a run either scores or it doesn't. At first base the call often hinges on ball or runner getting there as little as a tenth of a second earlier. The third baseman can catch a line smash if he gets his glove up in time, but if he reacts a split second slower, the ball goes into the outfield. In just this way, some ancestors of man survived if they dodged or hid, became a meal if they didn't, with the smallest fraction of time determining the result.

In other circumstances, especially where the distance between ancestor and possible aggressor was rapidly closing, a somewhat longer period of decision might exist, as in the instance diagrammed with the fishlike creature. In many animals this time factor creates a trigger distance: two dogs, for example, who might come together slowly without conflict may, if they surprise each other only a few

feet apart, immediately attack. Big-game hunters know the dangers of getting within the trigger zone in deep grass or other concealment.

In such instances the decision probably is being made at the reptilian level—the mammal downshifts. Time does not permit back-and-forth questioning of the environment and a search of recognition prosters; *to be wrong is to die* is the ancestral rule, expressed as "if there is no time to think, attack. Or if attack is impossible, flee."[4]

Thinking takes time. The computer vividly illustrates this: although individual electronic switching proceeds so rapidly that processing is measured in millionths of a second, a computing task may still take a computer minutes or even hours if sufficiently complex. In our bodies, moreover, systemic biasing involves a lag as hormones are carried to various parts of the body by the bloodstream. While we can act by muscle orders before the hormones take effect—as when we leap for the curb to escape an approaching car that surprises us—the hormones (the word derives from the Greek for "urge") are needed to maintain exceptional effort.

As any Little League coach knows, ballplayers must learn to evaluate the situation *before* a play occurs. A shortstop has no time to reflect on which base to throw to as he makes a stop—he has to execute a previous decision. Similarly, the skillful automobile driver decides to execute a left turn as soon as a certain approaching car passes, and does so, in contrast to the less able driver who lets the car pass, then decides—and finds another car is now bearing down, making the turn too risky. But we can make these advance decisions only in rather standardized settings, where they occur again and again. In Proster Theory terms, we build, by learning, a repertoire of programs, grouped (for baseball) as "two out," "bases loaded," "bunt likely," and other situational prosters—greatly shortening the recognition-decision-motor circuitry.

But obviously we cannot build and stock such short-cut prosters to cope with infrequent, surprising, or hard-to-recognize situations. Though the vast majority of these imply no threat to survival in a live-or-die sense, they nevertheless produce biasing, as evidenced in blushing, a flare of anger, change in breathing, tensing of muscles, dry throat, rising voice, tightening of "stomach," and so on.

Why should this be? Since the touchstone of this discussion is need, why do we have a gamut and variety of emotions?

EXHIBIT B

But today the concept of feedback is well established. We perceive in a *continuous* process, as we flow from situation to situation. Our brain's interest is in changes in the situation. And via feedback and a constant questioning of the environment, humans in good health vigorously probe for the information they need to live by.[6]

How do we steer a car down a road? We turn the steering wheel what seems the approximate amount required—the tyro's guess may be far off the mark, the experienced good driver's estimate very close—and then see what happens. If the car is veering to one side, a correction is made; the effect of this is noted and further correction made. The good driver makes many corrections, so continuously and smoothly, with little if any overcorrection, that the back-and-forth procedure of asking "How am I doing?" and getting the answer does not become apparent. Yet if one watches the hands on the wheel, the frequent tiny corrections can be readily noted.

If I go up a flight of stairs, I activate a much-used locomotion proster that enables me to lift each foot in turn to just about the right height to come down accurately on the next step above, but it is the feedback from the increasing pressure on the sole of that foot that permits me confidently to shift my weight to it. Reach up with thumb and forefinger to grasp the lobe of your ear firmly. Feedback from receptors, thousands of them, in arm and hand, give you knowledge of where your thumb is in relation to your ear; and as you grasp, the pressures on ear and fingertips tell how hard the muscles are squeezing. At every instant in these actions information is flowing both to and from the brain, and each flow is influencing the other.

The same is true in "outside" perception. Our receptors are not passive mechanisms, slaves to outside inputs. To quote Pribram, one of the relatively few investigators to wed psychology and neurology:

> A great deal of work has been done to show that the activity of all receptors, or at least the input channels from them, is directly controlled by the central nervous system. These "gates" allow the organism to be sensitive only to certain excitations—the gates in turn are self-adapting mechanisms, i.e., they are subject to gradual alteration by the very inputs they control.[7]

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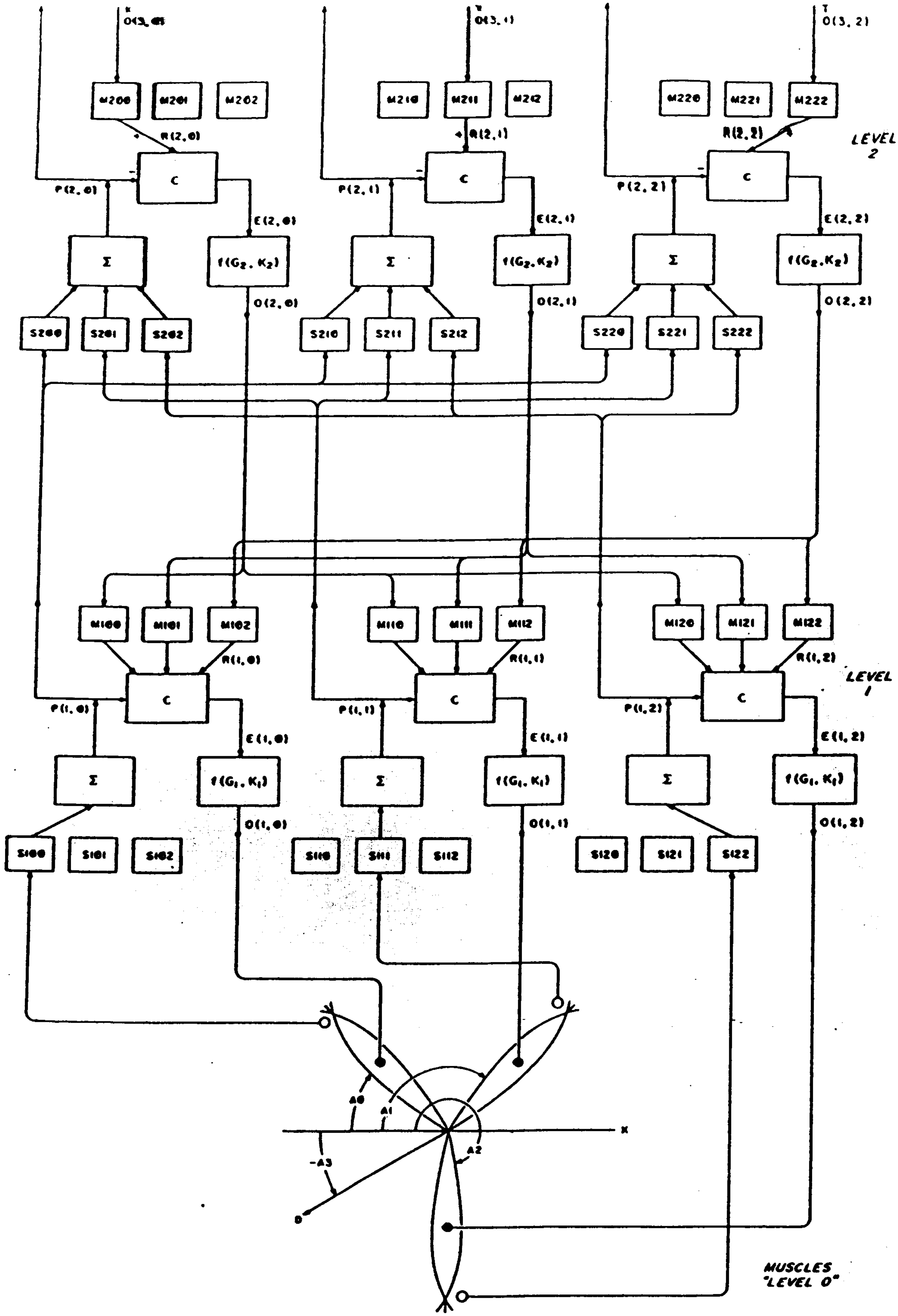
EXHIBIT C

Figure 15: The 2-level hierarchy simulated in this article. Three level-1 systems each control the amount of tension in 1 muscle, as represented by the 3 level-1 perceptual signals. Copies of these 3 perceptual signals reach all 3 level-2 systems, where they are weighted and summed so as to represent the X component of muscle force (P(2,0)), the Y component of muscle force (P(2,1)), and total muscle force or muscle tone (P(2,2)).

Each second level system sends an amplified and smoothed version of its error signal as an output signal to all 3 lower-level systems. Each output signal splits into 3 identical branches, 1 for each level-1 system. When a branch reaches a level-1 comparator, it may be connected directly or through an inverter before being summed with other reference inputs. There is no other weighting of output signals. If necessary, an inverter is used to preserve negative feedback for a particular path.

Each level-1 system amplifies and smooths its error signal to make an output signal reaching just 1 muscle.

A higher-level system determines the reference signals for X, Y, and total force. These are specified by the operator of the simulator. All systems correct their own errors simultaneously.



O(3, 0)
O(3, 1)
O(3, 2)
M200
M201
M202
M210
M211
M212
M220
M221
M222
R(2, 0)
R(2, 1)
R(2, 2)
LEVEL 2
C
P(2, 0)
P(2, 1)
P(2, 2)
E(2, 0)
E(2, 1)
E(2, 2)
Σ
f(G2, K2)
O(2, 0)
O(2, 1)
O(2, 2)
S200
S201
S202
S210
S211
S212
S220
S221
S222
M100
M101
M102
M110
M111
M112
M120
M121
M122
R(1, 0)
R(1, 1)
R(1, 2)
LEVEL 1
P(1, 0)
P(1, 1)
P(1, 2)
E(1, 0)
E(1, 1)
E(1, 2)
f(G1, K1)
O(1, 0)
O(1, 1)
O(1, 2)
S100
S101
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S122
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X
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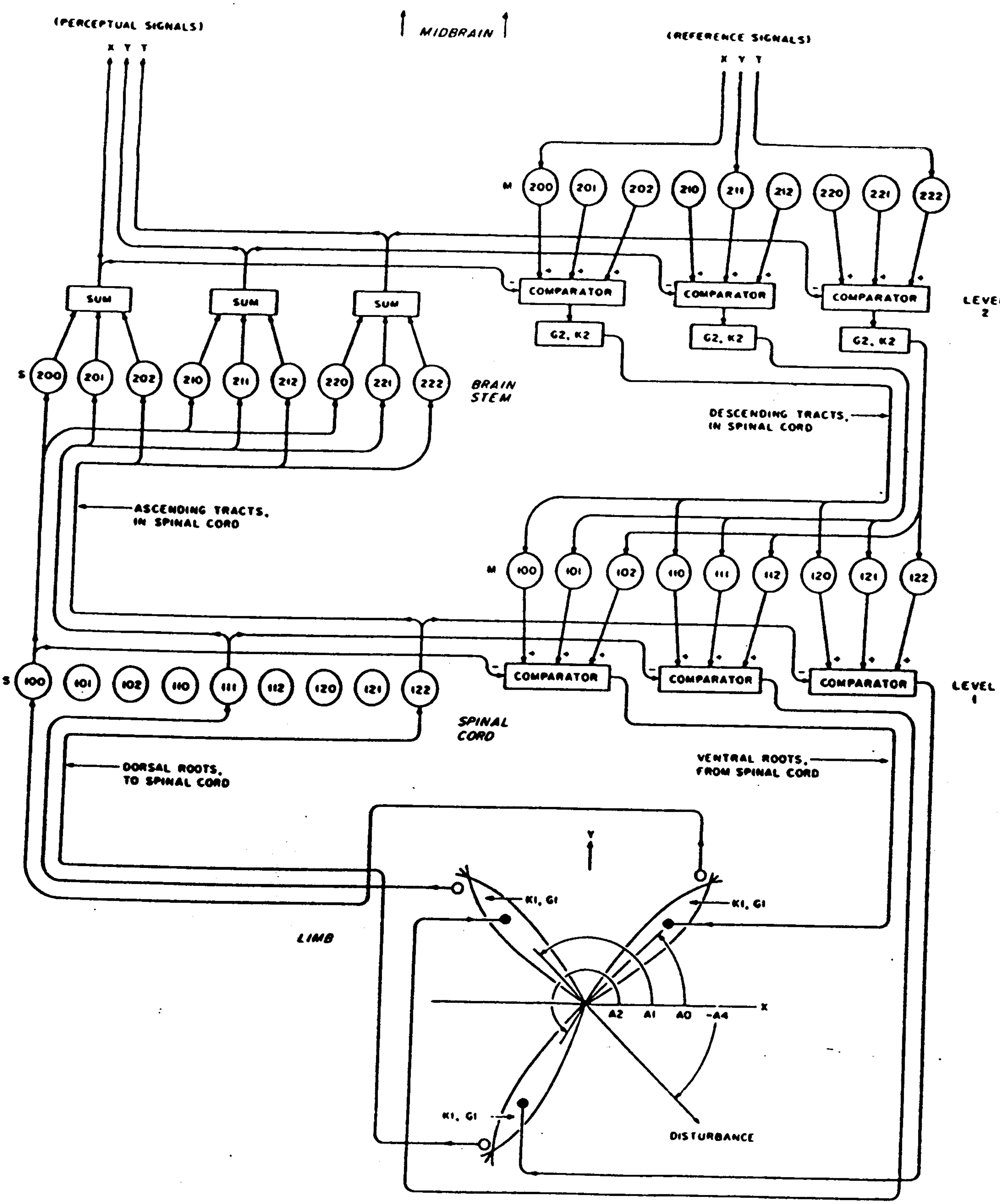

Figure 16: Topological transform of figure 15 shows how control systems are arranged in the human nervous system, at least according to some cybernetic theoreticians. The major difference from figure 15 is that all sensory functions are lumped together at each level, and comparison and output functions are also lumped together. The S and M matrices are represented in a nervous system as synaptic connections, the weighting of which is determined by the number of branches (from one to hundreds) that form just as a nerve fiber reaches the next cell body. The sign of a weighting is determined by whether or not a Renshaw cell (specialized to produce inhibition) is interposed. A collection of comparators and output functions is called a motor nucleus. For level 2 and higher, the branches of perceptual signals that cross over and enter a motor nucleus are called collaterals.