# OUTLINE OF A FUNCTIONAL MODEL OF THE NERVOUS SYSTEM

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*November, 1963*

## Introduction

The following is a rapid outline survey of the central features of a model of the operation of the nervous system. The first part will present the structure of the model. The second part will discuss a series of applications of the model chosen to help illustrate basic principles. The third section will present in the form of an overall scheme, without any attempt at justification, something of the larger semantic, social, and religious implications of the model. This presentation grew out of a short series of lectures. The lectures and these notes, based on them, are part of a large body of studies in rough draft form presently being rewritten for publication. In the brief discussion here we attempt no more than a suggestive outline.

# I. The Basic Model

## 1. *Apology*

What are physicists doing outside their field? Excursions outside one's own specialty are apt to be sterile and affected. However, a rather special situation exists today in our understanding of brain function. We believe that all the needed facts and principles are available in the literature, and that the only remaining block to a basic overall understanding of the operation of the brain is a purely model-building block. Because the problems that physics faces are so exactly repeatable and especially simple as compared to social problems, the art of model-building has there received its most advanced development. People outside physics rarely proceed beyond simple abstraction from facts in applying verbal models to the organization of data. They have little experience with or understanding of how a vast variety of seemingly distinct phenomena can be subsumed under common universals, starting with an abstract calculus (in the logician's sense of calculus) and proceeding by a process of construction.

The people studying the operation of the brain by experimental means have gone as far as is possible by the process of direct abstraction from facts. The field is now ready for professional model builders to come in and make an overall synthesis. Indeed every isolated part of the present model has been proposed and used by other people in some context. All that we do is pull these isolated principles together, and show they are all aspects of one common simple scheme or model, and that this model has a symbolic completeness, and an adequacy to explain in causal terms the overall aspects of brain operation, that could hardly be suspected when it was viewed piecemeal.

Being outsiders to the fields we are attempting to synthesize in our special capacity as professional model builders, we are sure to make a great many errors that experts in the field will be easily able to correct. But we believe that such errors will readily suggest their own corrections in the light of the basic model we are presenting. If we clarify this model sufficiently so that the professionals in the field can take hold of it, and push it on to a more adequate working form, we will have accomplished our principle aim.

We will now discuss the model in a series of stages, each one progressively more concrete than the proceeding one. As the model represents a radical new type of symbolic structure, we will begin by discussing its general logical status, and in what sense it will explain observed facts at all. For this purpose we will use the logical status of physics models to bring out points of similarity and contrast.

Then we will present an abstract functional model, exposing the difference between what we will call the parallel or brain calculator, and the series or conventional (IBM) calculators humans use.

This functional model will then be made more concrete in terms of a generalized conditioned reflex (CR) principle, notions of random search (RS), and steady state (SS) etc. to be defined and explained later.

Then we will discuss the problems of translating this abstract model into underlying wiring diagrams and give one or two basic applications. And finally we will develop an overall flow diagram of the logical processing of correlations by the model which constitutes the learning process.

Even at this level the model will remain highly abstract. None of the detailed functions of the various centers, or the various cell types will have been identified or discussed. However, even at this relatively superficial and abstract level of presentation of brain function a wide variety of specific experimental facts can be interpreted or predicted - a sampling of which will take up the second section of the paper.

This framework is one into which the detailed facts on the functional roles of the different centers and cell types can, we believe, be integrated. In so doing a vast array of special effects can be interpreted under common principles, as we hope to show in later papers. The main purpose of the present outline is merely to develop interest in our more detailed longer studies. None of this more detailed level of interpretation, where the role of the centers and cell types is analyzed, will be attempted in the short space afforded here.

At its best all we are presenting is a framework to be filled in, a framework for introducing a wide class of new structures, and defining a wide class of new experiments. It is a long road between early abstract quantum formulations, and the synthesis of all known facts of chemistry. We are only at a Bohr Atom stage of the operation of the nervous system. But we are at that stage. An overall causal model can be presented, or so we hope to make plausible, if not yet convincing in these brief pages.

## 2. *The Logical Status of the Model*

### a. Natural Philosophy

In Fig. I we have a schematic representation of the relation between facts and theory both in natural philosophy or physics, and in our model of the operation of the nervous system. This figure will form the basis of the present discussion.

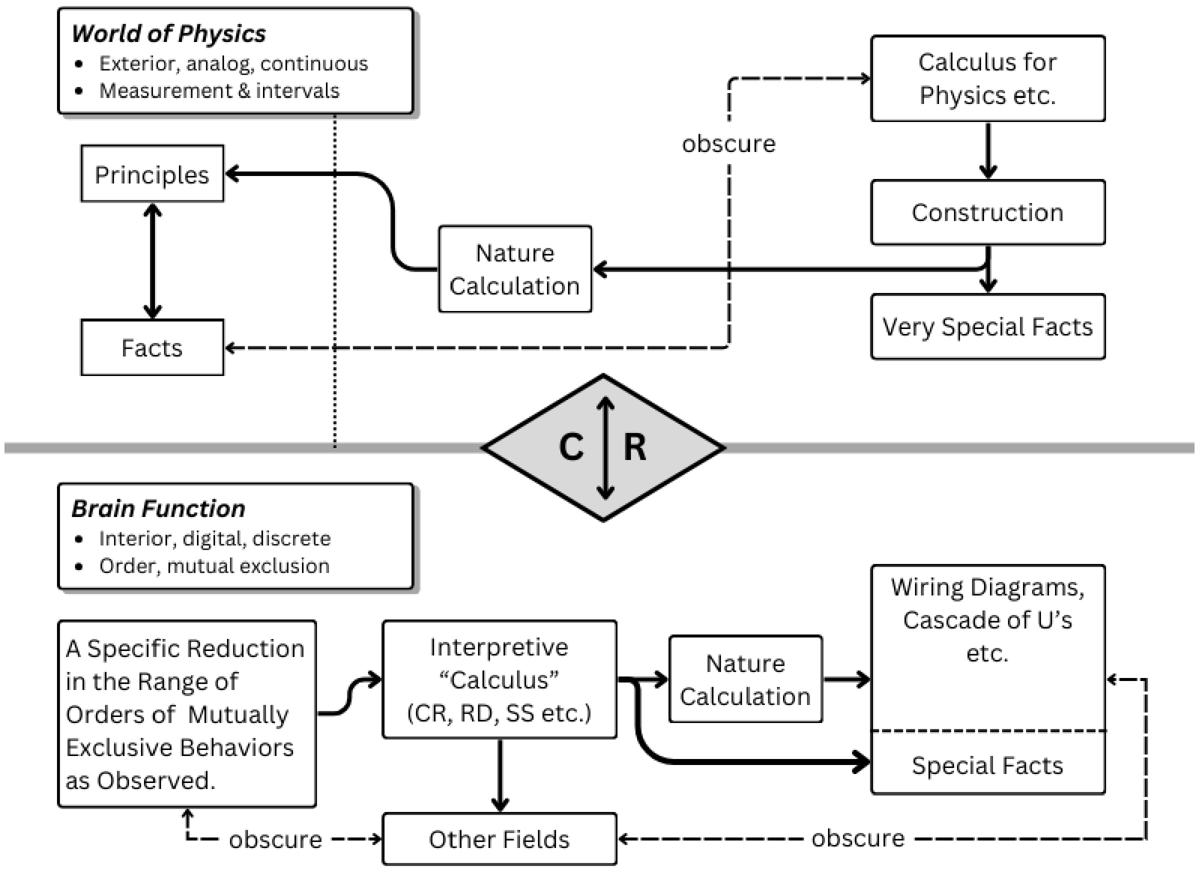



*Figure I: Physics and the NS Model*

The upper left hand section represents the early stages of a science when principles are regarded as directly derived from facts by abstraction. "All dogs have tails", or the similarity between breakdown patterns in adult life, and aspects of childhood behavior, are universals directly abstracted from facts. Such universals are organized in primitive models. As sciences progress a great pile of such universals accumulates. But in elaboration they lead to contradictions as among one another which contradictions gradually force up a new type of model whose function is to synthesize or resolve contradictions as among the principles directly abstracted from facts.

Natural philosophy is the study of these ultimate synthesizing principles. Its diagrammatic relation to the underlying facts is schematized in the upper right hand section.

In this case we start with an abstract calculus which has no obvious relation to underlying facts at all. (Here we use the word calculus in the logician's more general sense, as a set of proper symbols and rules for their combination.)

To reach actual facts we must carry out an elaborate process of construction, and even then we can only predict a restricted class of very special facts. These special and artificial facts are valuable only in that they provide a method of verifying the principles. To reach most everyday facts, as for example most of the facts of chemistry, we must use nature as our calculator. It is in practice impossible to compute the answers from the principles of physics alone. Nevertheless we feel that physics provides an adequate theoretical grounding for chemistry.

What physics does however is merely provide an adequate framework to resolve inconsistencies and guide research. If the nature-calculator step cannot be shown inconsistent with other known results, it is assumed to be a compounding of them. The calculus is regarded as a success when it can resolve inconsistencies, and provide an organization of the facts, even though it can predict very few of them. Indeed the crucial aspects of biochemical reactions cannot even be predicted in rough qualitative terms, let alone quantitative ones.

Many people outside physics are apt to operate on the semi-subconscious assumption that a synthesizing model should be able to at least let us calculate the known principles derived from facts. Clearly this is far too demanding a requirement. It is quite enough that it should provide a scheme in which the inconsistencies among the principles are resolved. That is, it must be possible to interpret the principles or gaps we cannot calculate directly as the result of “nature calculator" operations performed in accordance with the principles of the synthesizing model, and such an interpretation must lead to no inconsistencies. This much more restricted demand gives us a freedom of indirect construction or definition in model-building which is essential to finding an answer. There is a subconscious demand of "predictability" in many minds which often contributes to a sort of mental block. This block restricts models, in practice, to a variety of simple abstractions from observed facts (the upper left hand section of Fig. 1). To pass beyond this block requires the service of people who specialize in the arts of model-building. It is for this reason we feel we can be of service with only a textbook knowledge of the basic known principles of the field. These principles are now ripe for a deeper synthesis - being stuffed with the sort of latent specific syntactic contradictions needed to guide the building of more complex synthesizing models.

Now the basic orienting concepts of a synthesizing model are highly specialized ways of viewing and relating. The bare relevance of careful measurements of time and position of "things" to the synthesizing of the vast array of their "natural properties" is something far from obvious. Indeed there was once a day when philosophers argued over whether or not mathematical models could be usefully applied to nature, as today some argue over the usefulness and adequacy of their applications to the mind's operation. It was only slowly that the exact measurements of time and space were discovered to be key orienting concepts. The conservation laws represent a further extreme specialization of the measurement patterns regarded as "significant". Electrons don't "shout their numbers at us". The framework of physics is a fantastically special point of view. The relation between the wavefunctions of the quantum calculus, and the fact that the sky is blue, is a very obscure one.

### b. Principles of Brain Operation

Now let us turn to the discussion of the logical status of the principles of brain operation, and compare it with that of the principles of natural philosophy as discussed above.

First it is important to realize that we are not going to present a "model" of the brain, any more than physics gives a "model" of the world. One would look in vain in physics "models" for the earth and moon. What physics does is provide general procedures by which any given specific regularity in nature can be compounded of the unqualified universals of the calculus. Even these procedures are far from being reduced to an algorithm or automatic formula. They demand a lot of random search and "ingenuity", as the explanation of the phenomena of super-conductivity well illustrates. The adequacy of physics is based on its working success, not its reduction to an algorithm, in any strict sense. Physics provides a model of the “world" only in a very indirectly implied way. Actually, it is made up of procedures for compounding specific regularities out of the universals of the calculus or else showing they are matters of chance.

The wide variety of persistent regularities which may emerge from initial chance factors can cause great confusion in model-building when the status of this regularity is lost sight of or overstated, obscuring the chance element. With the chance element explicitly introduced, a wide variety of seeming incompatible universals can often be reconciled, and brought under common principles. To introduce chance elements does not make models less causal, and chance can enter in in many subtle indirect ways that are often not adequately appreciated. In order that a correlate be causal in our sense it must not be improvable by further qualifying the defining variables. Playing with dolls and having a long life expectancy are correlated, but to give octogenarians dolls will not increase their life expectancy. The correlation with dolls depends on the correlation between using dolls and age, and such further qualification improves the correlation. On the other hand, where chance components remain in the basic laws of physics, the correlation cannot be improved by further qualifying the variables. Only in special cases are causal correlations also unit (l00%) correlations. Nevertheless they are in a sense unqualified universals, in that the chance link they specify cannot within the framework of presently known facts be improved on, nor is it violated in any known case. In a context in which the laws of nature are being transcendentally differentiated no correlate can be regarded as causal in an absolute sense, unless limited in time, as to certain past facts. The causal character of a correlate is always understood as relative to the present body of knowledge, or present technical level.

Now many people outside physics tend to think of "models" in very concrete terms. They tend to expect that explanations will reduce to automatic algorithms. These expectations have served as blocks in their thinking, rigifying and restricting their imaginations.

We are not going to give a "model" of the nervous system, any more than physics gives a model of the world. Such a model, even in so far as possible, is largely confusing and irrelevant. A model of the solar system may hide implicit in it Newton's laws, but it is not the same as Newton's laws. Similarly, models illustrating the functional interdependence of the brain centers are useful when presented as illustrative manifestations of the underlying laws of brain operation, but such models do not constitute the laws we seek.

What then will the principles of brain operation consist of? They will consist, roughly speaking, of general procedures for translating specific steps in learning, or specific steps in reducing the randomness of human behavioral sequences, into underlying wiring diagrams. The totality of such translations will account for all human behavior, and the positioning of all wires, but no single model will ever be offered, any more than physics gives us a single model of the world. The model of the brain, like the physics model of the world, will only be indirectly implicit in the structure of the translation procedures.

Now physics, as a method of resolving inconsistencies among natural principles derived by abstraction, and so systematizing them, takes a very specialized point of view. There is a vast redundancy in nature. The same fact can be oriented in endless different ways - by its colors, by its odor, by the people that know it, by the places it is near, by the position of the stars at its discovery or creation, etc. The key orienting concepts for systematizing the patterns of inanimate nature has turned out to be exact measurement of time and position, at least relative to the class of phenomena of classical physics.

What corresponding method of orientation will arise in systematizing brain operation. What special aspect of the life process will come into prominence in systematizing brain operation - as measurements of length and time orient or help systematize physics. The answer lies in a concentration on changes in the order of emission of mutually exclusive behavior patterns.

This point of view is of course fantastically specialized, as is that of measurement. However, the redundancy of nature is such that the totality of behavior can be compounded of such factors in endlessly different ways, and we need some further guide as to just what aspect of these order changes to concentrate on, just as we need a guide as to which measurements to focus on.

The order changes we will concentrate on are closely related to steps in learning. We will concentrate on changes which have the symbolic form of reductions in the range of possible random or semi-random emitted sequences of mutually exclusive behavioral factors. This concentration might be analogized to the space-time ordering of measurements which underlies all scientific thought, and is so taken for granted today that it is hard to make people realize there is anything special about it. For people who are oriented in terms of magic and spirits, so central a role for space-time ordering can seem a truly revolutionary assumption.

Starting with a specific order of emitted behaviors to be explained we analyze it to show how it was compounded by a finite sequence of changes of the more special type described above which closely parallel the learning process.

The general method of analysis of a given behavioral sequence, as a compounding of subsequences, has at its core a set of concepts which could be compared with the orienting calculus of physics. They do not, of course, constitute such a calculus, but rather a set of special concepts, ultimately compoundable of the calculus of physics, and comparable to the special concepts of chemistry or engineering.

Now the function of this “brain calculus" is somewhat different from the calculus of physics in other ways too. It is perhaps best viewed as a method of systematic translation of specific changes or narrowings in the order of emitted behaviors, into underlying wiring diagrams of nerve connections that could effect such changes.

The special concepts used as part of such translation (the conditioned reflex (CR), the operation of establishing a relative dominance (RD), and the steady state (SS) condition, etc., to be explained later) represent yet further radical specializations in our point of view, comparable to the specialization on certain aspects or special functions of spacetime intervals implicit in the conservation laws of physics.

The actual translation into underlying wiring diagrams will, for the most part, make use of "nature as calculator". Only in relatively artificial and special situations will the specific wiring be defined. For the most part, the model only indicates classes of possible wiring changes that might contribute to the result and which the laws of brain operation might lead us to expect were involved. Thus physics suggests that a certain type of exchange force may play an important role in a certain binding, but we must use our nature calculator to test exactly what that role is, or, in the case of the nervous system, exactly what wiring was effected.

The natural linkage to other fields, such as the various schools of psychology, or historical phenomena, or philosophy, will occur via the "brain calculus". The relation between the concepts of other fields, and specific changes in the order of emitted behaviors, or wiring diagrams, will remain obscure.

### c. The CR As the Link of Two Worlds

We have, in effect, two worlds. One is the “exterior" world of physics, oriented by concepts of measurement, and comparison of intervals. The other is the interior world of brain operation, oriented on concepts of order among mutually exclusive elements. The outer world is continuous, the inner discrete.

Now the linkage between these two worlds can be symbolized by the conditioned reflex principle, or the properties of interactions between nerve pairs.

A nerve is to a first approximation an all or nothing device. Various classes of stimulations of the dendrites or the receptor ends, fire off the cell body and axon. The dendrites respond to what might be called a one-dimensional local parameter running from "inhibition" to "facilitation". With sufficient facilitation the axon fires. If the axon fires at all, it fires in only one way.

In this respect it is a digital device. It is only the firing or non-firing that is significant, not the amplitude. Nerve cells never divide after birth. Some run the whole length of the body.

Now in certain areas these nerve cells interact in ways described by what one might call a generalized conditional reflex (CR) principle. If the firing of an axon ending is correlated with local excitation in the area of that ending at the time of firing, some change takes place whose exact nature is not yet fully understood, but which serves to facilitate firing in that area in future when that axon is fired. And, in reverse, if the area in question is especially inhibited when the given axon fires, its future firing tends to produce a local inhibition there.

The CR principle forms a link between two worlds. On the one hand externally imposed correlations, or correlations of external origin, become internal ones as well via its action. Thus the local coincidence effect is raised into a universal that can influence future events.

The world can be usefully viewed as one great calculating machine with a combination of analog and digital parts. The outer world and the body representing the analog side, the interior nerve links representing the digital side. The CR partakes of both aspects. Continuous parameters are involved in its definition in that the frequency of firing, the travel time of the pulse, the degree of excitation needed to fire the cells, and the circumstances controlling this excitation etc., are all subject to continuous variations, if not in a given cell response, then at least in the parameters distinguishing cells. The CR response is digital in that the amplitudes of the specific firings are not used to carry information, and also in that distinct paths or distinct patterns rather than continuous variables are used to carry information.

The CR thus forms in several ways the link between the inner world of order, the digital world, and an outer analog world of continuous change, or measurement.

Our present studies will concentrate on the more digital or purely pattern aspects of brain operation. Response involves many analog aspects as well, but for the most part we will take these analog aspects as empirical givens. The detailed study of these quasi-analog effects, such as thresholds, and time of response etc., involve a range of phenomena largely outside the concern of the present studies. That aspect of human behavior called "meaningful" is almost entirely on the "digital" side or pattern side. Continuous variations in the pattern (as of these words) are regarded as meaningless until they change the pattern altogether.

The failure to separate out the pure pattern or order aspects of brain operation has been another source of deep confusion, since it leads to an obscuring of the basically simple core of laws, or a confusion of these basic laws with secondary effects. As in physics, so in brain operation, to get oriented one must learn to look at the world in very special ways, or else all seems a chaos of interdependencies leading nowhere, that is subsumed by no common principle.

People outside physics often fail to realize the enormous redundancy of the actual world, how any one point of view can be elaborated to include others, however specialized it seems at first. Color and weight and chemical changes all are compoundable of and usefully predicted by, changed patterns of length and time intervals of a special type. So too all human behavior can be viewed as compounded of many small steps in the reduction in the order of possible emissions of mutually exclusive behavioral factors. To do so, behavior must be analyzed in great detail. Each twitch in the body's random thrashing constitutes, for certain purposes, an element of behavior. The road is often a long one, as the road to explaining superconductivity is a long one, but the simplicity of the building block (in our case mere order difference), does not, as we shall see, preclude a complex edifice. Order changes have their analog aspects that have a "logical feedback" changing the class of mutually exclusive behaviors we deal with. The CR principle links two worlds. By tracing this linkage, and leaving most of the work to "nature calculator", or indirect forms of definition, we hope to show how already well-known principles form the embryo or starting point of a complete and adequate system of exploration of brain operation.

### 3. *Series Versus Parallel Operations*

Some comparison of the brain calculator, with the better understood digital calculating machines may help orient its overall functional character. A conventional digital calculator is a programmed adding machine, in which many millions of operations may take place, one after the other, in series, at high speed. Any error in anyone of these millions of series steps usually makes the final answer altogether absurd.

In contrast to this conventional "series" type calculator, the brain may be viewed as a parallel calculator in which not one, but thousands of actual and potential processes go on side by side influencing each other. Actual calculations in such a "parallel" calculator involve only a relatively small number of series steps, but many independent parallel factors contribute to the selection of each step. In a parallel calculator there is plenty of room for errors in the various parallel branches without effecting the final result, since redundancy can be used via effects of cumulation to distinguish the "true" answer in a wide variety of ways.

Now a parallel calculator contains a wide range of random connections adapted to picking up correlations. Indeed this forms what might be viewed as its basic functional distinction from a series calculator. The parallel calculator is designed to pick up correlations, to sift for and isolate new significant correlates. The series calculator is designed to help establish the consequences of correlates already well defined. Of course these distinctions are not absolute. But they do represent dominant aspects of the functional specialization of each type of machine.

Because of the parallel operation, and the use of redundancy and cumulation to distinguish, a parallel calculator can operate way beneath the "noise level", so to speak.

Only a small fraction of existing nervous activity is ever relevant to the present conscious state. As in an FM radio set, so in the brain, redundancy is used to allow a wide range of interaction, and still pull out the dominant. The recognition of this greatly simplifies and extends possibilities of brain design in ways that at first glance would seem to represent too great a mutual interference of paths for consistent reliable operation.

## The Chain Model

We have now to examine this parallel function in somewhat more detail. We will start with a loose abstract functional formulation, which we will make more concrete in the next section. In a later section, we will discuss how to translate these functional schemes into wiring diagrams. We will first position the wire in an indirect functional way, rather than in spatial terms, and only later discuss the problem of spatial positioning.

In a loose overall functional sense one might say that the nervous system links together the past historical sequence of acts, so that if act B followed act A in the past, then the facilitation of act A or its occurrence will tend to facilitate act B as well, and up the probability of its (B's) occurrence following A.

The sensory inputs only function to help intercorrelate associated acts, but do not initiate acts directly. Thus the ringing of a bell, followed by feeding can condition a bell-dependent salivation response, but this response arises only if the dog is hungry. The sound only functions to interlink a random search initiated by hunger with a salivation, it does not of itself cause salivation.

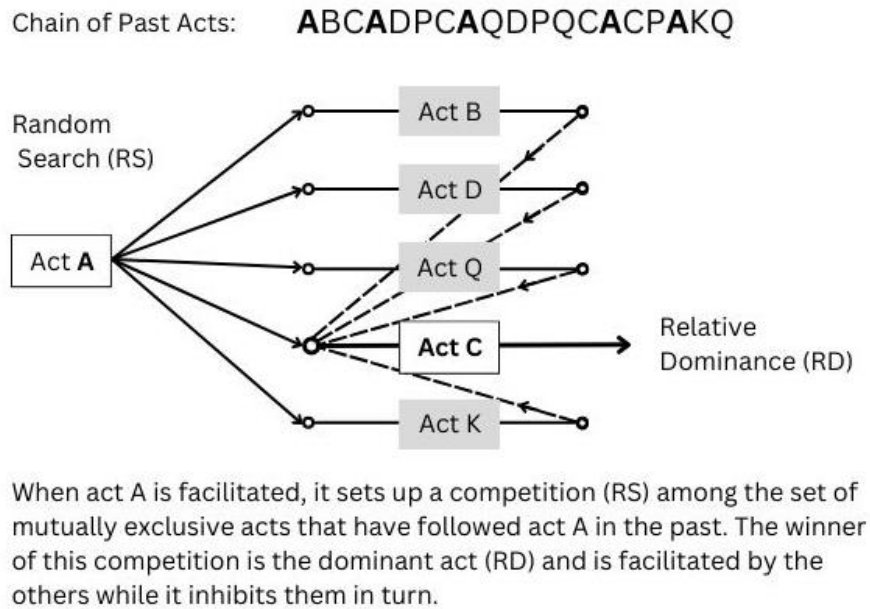
A life can be crudely viewed as a long chain of acts, say ABCADPCAQDPQCACPAKQ etc. Now consider the above sequence of acts. Act A has been followed in the sequence by acts B, D, Q, C, and K. Hence by the generalized CR principle all these five acts should be facilitated at once when act A is next facilitated.

This breaking-up of the life chain into pieces and bringing these pieces into parallel is a basic function of the nervous system. They are brought into parallel only in and as they are competitive factors, i.e. capable of following a given act (A).

Now the basic operation of the brain as a parallel calculator may be regarded as that of establishing a relative dominance as among these acts brought into parallel in this way. Let us suppose that C is the dominant act. Then the establishment of a relative dominance in the set (B D Q C K) would mean that the facilitation of any of the branches B D Q or K would lead to the facilitation of C, but that the facilitation of C would lead to the inhibition of B D Q K. The rejected branches are used as an essential part of the mechanism for conditioning the dominant branch, C.

This use of rejected branches to condition the dominant has, already at this early stage, the seed of a revolutionary simplification of the conditioning process. Because the dominant is not defined directly but only indirectly, relative to the rejected possibilities, it is much easier to condition, or compound out of simple unqualified universals like CR's than might appear at first. One has not merely the proceeding act, but also the whole class of acts which have previously followed that act, to use in defining or selecting the dominant. It must also be remembered that this class is itself shaped by present sensory inputs, and will include not merely acts, but also act sequences. The sensory inputs that intercorrelate the motor factors, include internal sensory factors, sensitive to the state of excitation of various parts of the brain as well as body or muscle states.

*Summary Illustration: Random Search and Relative Dominance*




This breaking up the chain of past history into pieces brought into parallel and establishing a relative dominance (RD) as among them, is the basic operation of the nervous system. We must now examine this process in more detail, to see what factors define an equivalence class, and what criteria operate to select over that class, and so define an RD.

### 4. *Stopping Random Search*

A particular equivalence class can also be viewed as a random search. The elements of the class are mutually exclusive in that two may not occur at once. This mutually exclusive character is maintained by reciprocal enervation. That is to say the strong facilitation of one of the acts inhibits all others. This concept of reciprocal enervation which Sherrington did so much to expose and clarify in connection with the spinal reflexes, is also basic to the organization of the whole brain. We are taking it over here in a somewhat generalized symbolic form, as the nervous basis of the separation of the mutually exclusive acts.

Now a random search (i.e., the set of acts searched over randomly in connection with a particular drive factor) may be regarded as a class of repeated acts which may follow a given act and have a certain competitive equivalence. A given state of excitation of the brain will have its own associated class of emittable acts, which function to lessen this excitation, and stand in a competitive relation to one another. This class could be called the associated random search (RS) of this state of excitation or this "drive factor".

Now these random searches or classes of equivalent acts are excited and shaped up by a wide variety of variables. Basic sources of random search in the early development of the child are hunger and discomfort. A pain in the toe excites a different class of "thrashes" in an infant than hunger or cold. And even where the class of thrashes overlap, they may be regarded as adequately separated when excited by different factors, since only a small fraction of the nerve cells associated with a given muscular contraction are ever fired at once, so the class fired is sure to be a function of the exciting factors.

Thus we begin our analysis with many classes of random search, selected by what one might call drive factors, and further shaped by sensory factors that serve to intercorrelate motor outputs.

Now what is it that determines the dominant? Basically, what determines the dominant in a given random search is that combination of motor factors that stops a particular search.

The combination, hit on by accident, which stops the random search, will be the last one to be tried in the sequence excited by the drive factor associated with the RS. And this tends to give it a preference when tried again. In the random search set in question it follows others, and others do not follow it. But deeper than this is the fact that any other "momentary RD" which does not stop the random search, cannot be stable - and hence cannot constitute an RD. The random search will force up other sequences, and so force a shifting of the interconnections as among the search components. Only those correlations which stop the random search in question can be invariant, or take hold. Hence, from certain points of view it is often useful to speak of that correlation of search factors which stops the random search and so establishes an RD as the invariant correlate.

Now the engaged motor factors in a given random search are highly individualized, and become progressively more so. Sensory factors, the surrounding motor factors into which or from which the given random search proceed, all serve to individuate that search. The "same search" may be repeatedly returned to and gradually solved out in stages. Certain gross correlates may reduce the random search and these restrictions, by allowing a more intense examination of the remaining combinations, serve as a basis within which "more invariant" correlates can be found.

It must also be remembered that the human organism emerges into an environment specially tailored to help point out or reinforce that precise combination of sequences that will stop or narrow random search. This fact greatly simplifies the learning process, of course. Lower animals have their development locked in and limited by instincts, and are accordingly as isolated individuals less dependent on special group learning environments. On the other hand, as a group we are far less tied to a special environment than the lower animals, and for the same reason. A bumblebee would be lost outside its ecological niche, for which its instincts are adapted. Men can reform his "instincts" to the needs of any niche.

The analysis into random search factors is a little like the two-body problem in physics. There is only a two-body physics. More complicated situations are treated by perturbation theory, which is a sort of succession of two-body problems. Three-body problems are insolvable in their full generality.

So too in treating the organism we analyze the repertoire into specific random searches. In fact, these random searches interact of course, and the separation is never fully justified. Nevertheless where these searches interact they can be treated as compound or interacting simple searches, as we treat by perturbation theory. That is we may, for example, take the RD of the 1st search solution, apply it to the second search to shape that field, and then take the RD of the 2nd search and use it to recalculate the 1st search, etc. The separation into random search factors is a very general method of analysis - like Fourier analysis. Many many sources of random search are present, playing on and exciting the motor centers each in its own individual way. Each will have some class of motor sequences that stop or reduce it, or reduce some aspect of it. Human behavior has many dimensions, and many time constants. What stops a random search is reinforced again and again. Being invariant, it can take hold and push to the surface, displacing the many competitive factors or connections implicit in the semi-random interconnections of the brain.

Now an RD that takes hold relative to one random search has a logical feedback, reshaping all the others. This logical feedback may involve analog as well as digital factors. Also the RD established relative to one random search may be incompatible with others and upset by the effect of others, so as to produce an alternation. Behavior successful in one context, fails in the next. This compound alternation between pairs of competitive RD's can be itself viewed as a random search, to be resolved by finding some more elaborate RD that satisfies, or is invariant under, or stops both random searches at once.

The analysis into random searches, associated sources of facilitation to be stopped, and associated RD, is thus a very flexible tool. As with measurement in physics, so too here, unless one measures the right things, unless one picks the right random searches, one will not get at a causal explanation. Physics requires ingenuity in its application. It is far from reduced to an algorithm. The crucial structures are only indirectly or implicitly defined, and in each new application some distinct new configuration of the same basic concepts must be devised to compound the observed regularity of the unqualified universals of physics. This same will prove true in the application of the present brain model.

## *5. The Steady State Condition*

As more and more RD are discovered via the infant’s interaction with its environment, the repertoire becomes sufficiently intercorrelated that chain links may be excited several stages ahead. This is accompanied by a reduction of response levels, because the rejected branches are used to condition (i.e. provide additional facilitation for) the dominant branch, and isolated branches are no longer so excited as to be able to exclude others and take off on their own without the support of such cumulation effects.

Now this internal "predicting ahead", or facilitation of successive motor factors is apt to reshape the effective RD’s in such a way as to modify the next step in the chain. The initial "assumptions", or RD's with which we started, that first defined the loop representing the "next" act are redefined before that loop gets a chance to repeat and recruit enough to give rise to the associated emission of the "next" act, and a new loop representation of the "next" act is selected.

As a result, a certain internal hunting process which closely parallels the external search process is set up. The paralleling occurs in a highly foreshortened symbolic form; nevertheless it has the structure of the external search, only internalized. The internal search is concerned with latent inconsistencies in the RD established by the external search. The internal search is generated, as it were, by the over-defined, or over-generalized character of these RD's as first internalized. The components internally searched over are thus more highly individuated than the external search components. They correspond to alternations as among established competitive external RD.

Now this internal search process will continue till the series elaboration of the "next" step, that is, the steps that follow it, are not such as to undercut this "next" step. When this occurs a steady state is reached relative to the given internal random search in question. The internal random search stops, and a repeating state is achieved that leads to recruitment and enactment of the act in question.

The nervous system has the property that any repeating cycle augments, and leads to the enactment of the motor factors associated with it.

Thought can be viewed as such a search for steady cycles. It is a search for RD that stop the internal random search. When this is found, the associated act is emitted, or "decided on" - and attention shifts to other random searches which were inhibited by what may be regarded as a generalized form of reciprocal enervation, while the first one was being acted out. The result of the second RS will often be to introduce RD that upsets the 1st RD, so that one has in effect to consider a compound random search with a new enlarged range, of freedom, or range of mutually exclusive competitive motor factors.

The differentiation process goes by a series of such successive approximations, searching for invariant RD that satisfy all drives, or all random searches at once. The search is to find a set of spanning invariants. Because of the close parallel between the internal and external search process, such spanning invariants have a predictive character, the character of an actual foreshortened model of the world. The prediction is first of our acts, but predicting our acts involves predicting the world. Our dominant coordination in bouncing a ball has implicit in it the laws of physics as applied to falling objects. Our behavior in. boiling water has implicit in its ordering aspects of solid state physics.

The internal steady state is the basic shaper of conditions of reinforcement. What leads to an internal repetition or ringing receives far more support than any specific external stopping of isolated external random search could ever effect.

Any factor which contributes to this overall steady state, or narrowing of random searches, becomes reinforced in that it is repeated. This can be viewed in a variational way when internalized. That is, adjustments may be viewed as locked in by the variations from those adjustments, which variations augment random search and so are explicitly rejected, or not reinforced, which amounts to the same thing.

Any new correlate, any new stimulus has associated with it a set of implied internal and external random searches, because it is apt to upset old RD. When these are acted out, i.e. when stable new RD are established, attention passes away from the new correlate or stimulus which may then be called "integrated".

The new correlate enters as a conditioned reflex. Now a conditioned reflex has no internal basis of regulation. If act B becomes correlated to follow A, the conditioned reflex principles make B follow A faster, more often, and more vigorously, till it touches or excites counterfactors that regulate these tendencies. Regulation or integration occurs only by such successive contradiction.

The sensory inputs only function to help interlink the motor outputs. They have a subjective character only in and as they engage or link motor sequences. A particular room or sensation engages the class of motor sequences which occurred in conjunction with it. Loops exist in the brain as parts of sequences in which successors inhibit predecessors. They continue only as repeatedly recreated, which restriction is an essential part of their regulation. What repeats is emitted.

The role of the sensory factors can thus be accounted for in terms of their function in engaging motor correlations. The motor correlations provide an orienting core in representing both the details and overall character of brain operation. Other factors are most simply treated via their effect on these.

All correlates, being interpretable via motor correlates, have their aspect, when internalized, as RD's with respect to other competitive motor correlations, which competitive factors enter into their conditioning. Now RD’s such as are implicit in new correlates are regulated via the random searches they excite in old centers that they throw out of balance. The RD’s in the induced random searches constitute regulating counterfactors. The CR or RD is regulated via such pushing to an extremum only, i.e. via contradiction only. There is no internal basis of regulation.

The internal random search induced by new factors first spreads and creates a broad involvement till this touches sources of RD somewhere among the interlocking sets of induced random searches invariant enough to start a "collapse" or guide a resolution. RD's must be found that are not upset by the RS’s they induce, and so guide the setting up of RD's in these other RS's. The parallel structure implicit in these series of internal occurrences then forms itself into RD's adequate to define the stopping sequence or paths.

Now in the steady state condition a large number of internal CR factors are in effect compounded. Many people have felt that the Pavlovian CR approach was inadequate to account for the wide variety and adaptability of observed human behavior. This would indeed be the case if the emitted behavior were the expression of one CR. But via the internal RS and steady state (SS) condition, we compound a wide class of CR's in the determining of a single act. The CR's can be regarded as entering into the SS condition and forming lt, much as many specific mathematical terms enter into the expression of a condition requiring no divergence or conservation. If we consider that the environment acts selectively with respect to the class of CR's or universals compounded, we can easily see how a relatively few factors could give rise, via SS compounding, to a seemingly almost limitless variety of emitted behavior.

Thus one room engages one class of motor sequences, the color red another, the books and paper in front of us yet another. The internal wiring remains the same, but the class of CR’s engaged to form the SS changes as we change environments, hence the emitted acts also change.

The learning cycle, and the cycle of daily life, are formed of classes of interlinking RD’s and random searches that go to make up the detailed structure of the steady state. Whatever is not specifically upset as "next step" is emitted. RD’s can often be set by mere 1st choice, as when the random search is over which chairs to sit in in a classroom, and this RD can hold the term long, indeed lifelong. Other RD’s may arise from touching special sources of stimulation, such as the noise of a rattle. All these RD’s compound in the SS via the various learning cycles or life cycles that if not satisfied will upset the "next" step. It is only the stability of the series elaboration and associated RD’s that keeps "quiet" the associated drive factors of these cycles.

The RD and SS provide an abstract functional framework within which to define the location of a given behavioral or thought sequence. We have now to consider how this location may be used to guide translation to underlying wiring diagrams capable of causally inducing the given behavior or thought sequence.

## 6. *The Translation to Wiring Diagrams*

A schematic diagram of the overall wiring is shown in Fig. II.

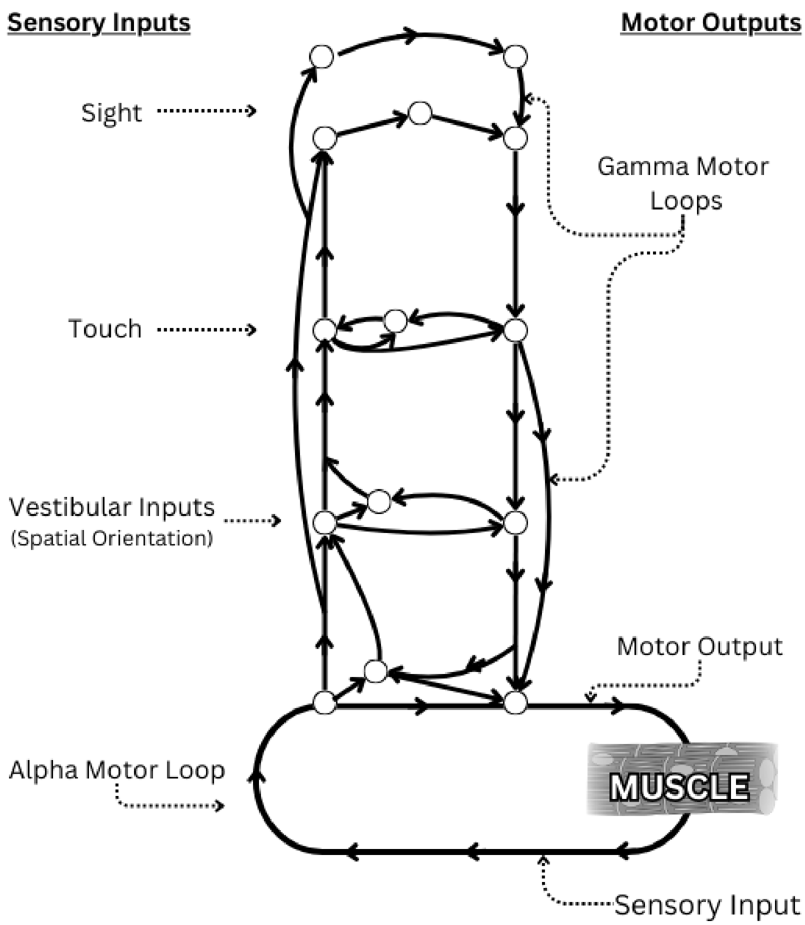



*Figure II: The Cascade of U's. The vertical column of U's represent the brain and the spinal cord. Sensory inputs of 3 types are shown, represented schematically by arrows. These sensory inputs play upon the gamma motor loops at various levels in the brain and cord. The gamma loops in turn control the level of excitation in the alpha motor loops that regulate the muscles.*

At the bottom are the monosynaptic loops to the muscles. Sensory inputs from a given muscle excite directly the horn output cells that tighten that muscle forming a loop with only one synapse, i.e., only one point at which the nerve impulse passes from one nerve cell to another. The gain of this loop may be crudely regarded as of the order of unity, that is the sensory inputs are just about enough to maintain the horn cell outputs that tighten the muscle. The upper parts of the brain have their influence on behavior by raising or lowering the gain of the lower loops.

When the gain is raised above one, the muscles tighten. When it is lowered below, one, they relax. The gain of these loops is not constant, being a function of amplitude as well as past usage. At low amplitudes the gain can often be regarded as increasing with increasing amplitude, or continued usage. With high amplitudes and long usage the reverse is true.

The lowest loop is made up of large fast alpha wires, while the regulation from above is made up of slower, smaller gamma wires. It is a basic principle of servo-loop design that the regulating loop time constants must be longer than that of the loops they regulate. The slower gamma activity precedes actual contraction by raising the gain in the monosynaptic alpha loops. Then the gamma facilitation from above collapses previous to the alpha collapse, controlling it at every stage.

Now the sensory inputs from a given muscle rise to make direct and indirect contact with cells at upper levels which in turn fire on up, or back down to lower levels, where they contact the motor outputs (see Fig. II).

In the figure the sensory inputs from the muscles may be regarded as a sort of river that spreads out and then converges back into motor output channels at three upper levels, which form a sort of ladder.

These upper levels are played upon by various sensory inputs which may be regarded as serving to make the passage of the sensory muscle stream easier at that point.

Now associated with the tightening of a synergic muscle group will be upper loops which arise because of interconnections between the motor outputs and the corresponding sensory inputs at higher levels in the ladder (Fig. II), built up because of the CR principle itself. These loops in the upper rungs of the "ladder" are such that if sufficiently facilitated they fire off the lower rungs and the associated act.

Now the underlying muscle factors are organized in patterns of reciprocal enervation. That is to say the facilitation of one act or act sequence inhibits others. From a wiring diagram point of view, for example, the same wires that help tighten extensors may inhibit flexors. This will induce a corresponding reciprocal enervation among the loops in the upper rungs of the ladder. Thus the upper loops serve as a sort of internal symbolic representative of the external mutually exclusive motor acts or act sequences by which they were first induced, and which they facilitate. If act A inhibits act B "below", or in the spinal reflexes, the loop representative of A will be negatively correlated with that of B in the higher rungs of the ladder, so that the same pattern will repeat itself above.

The concept of reciprocal enervation as thus generalized is seen as a basic principle in organizing not merely the spinal reflexes, but the whole brain. It is manifest, for example, in Pavlov’s "negative induction effect" in which the strong stimulation of any point on the cortex tends to inhibit responses from other areas. This postulated effect has been more recently directly confirmed by direct cortical stimulation.

Now certain of the upper loops may be regarded as having decay times of the order of several minutes. Memory requires some ten minutes of ringing for permanent establishment of the link. People forget what happened for about ten minutes before a concussion of the brain.

The sensory inputs serve to help interlink the motor factors. Cells that respond when local activity in different parts of the brain itself starts or stops form an essential part of these sensory factors and might be called "internal" sensory inputs as distinguished from more "external" sensory inputs from the eyes or muscles. The sensory factor makes the passage of the motor link easier at that point. Sound and sight are both confused with touch in their early stages of integration, and at "subconscious" levels of influence even in adult life, as in the echo location the blind "feel".

From a wiring diagram point of view this playing of sensory factors on the motor streams occurs in what are called association areas. The difference between stimuli that enhance the chance of passage and those that cause actual passage of the signal corresponds to the difference between dendritic excitation versus cell body excitations, roughly. The dendrites can be excited, and maintain an increased level of excitation for some time, without firing off the cell body, while serving to increase the probability of such a firing by more direct connections.

The reciprocal enervation in conjunction with drive factors which preferentially excite distinct centers define a variety of classes of random search. The motor sequences that occur in these classes are in part a matter of chance, in part a reflection of the correlated structure of the environment (the wall is always to the left, an open hand can only be closed, etc.). These motor sequences may be regarded as linked together in the upper rungs of the ladder. A motor sequence is here represented as a set of loops each of which excites a successor which in turn quenches its predecessor out. The upper loops find subordination and regulation via their relation to the underlying motor factors. If they rise beyond a certain point they engage these factors. It is only via this constantly changing pattern of mutual quenching action that the upper loops maintain a quasi-independent activity without repeating and firing off lower rungs so as to cause the emission of an act.

Now the breakup of the life chain into parallel factors may be regarded as embodied in a similar breakup of motor loops into parallel groupings in the upper rungs of the ladder. The establishment of an RD as among them means that the recessive loops have collaterals that facilitate the dominant loops, and the dominant ones have collaterals that go back and inhibit the recessive ones.

A wide variety of random searches of vegetive origin, such as hunger, are initiated in the hypothalamus, acting on these upper U‘s. At first the little child has no idea what it is searching for, and all searches seem the same. Only slowly are they separated.

A particular random search may perhaps more realistically be regarded as solved by an act sequence, say A B A, rather than a simple selection of an act from within the set of mutually exclusive random factors forming the search. Also this randomness is in fact only a rough functional idealization. For the most part, fluctuating correlations wash each other out, and can be approximated as random, unless directly relevant.

Now a relative dominance may often depend upon the intercorrelation effected by some specific sensory input. This branch then "allows" as it were the bringing into parallel of the paths it dominates. The brain is a device with a vast array of semi-random interconnections. If any of these is such as to be always reinforced, then it will, by the CR principle, and the ringing condition, gradually grow in importance, till at last it takes over and establishes an RD in the search class in question. This tendency of invariant correlations to push to the surface out of the statistical mess we might call correlation pressure. The most invariant ones dominate the others. Random searches can be formed in a wide variety of ways, and correlates from one random search can be further refined via others in step-by-step fashion. Though most random searches have no "future", that is they fail to catch stable invariants, some somewhere do. These compound, being propagated by imitation, eating slowly into the unknown, like acid, at every small crevasse in those random searches that open, i.e. whose RD's are stable enough to stand up under generalization and support further differentiation.

The original simple loop bundles associated with the unconditioned reflexes, or "instincts", are by this process gradually broken up into mutually excluding pieces. This breakup is accompanied by the cumulation effect, in which the rejected possibilities form part of the essential stimulation defining the dominant.

Series elaboration drops drive levels by the inhibitive effect of successor acts on predecessors. It continues to drop these levels till they become too low to define or bring about needed emission, at which time a countercompensation counteracts these tendencies. The existence of cumulation effects allows drive levels to be reduced without stopping emission. Thus drive levels drop, and isolated loops cease to be able to go off on their own. Cumulation becomes essential to emission, and the internal life begins to open. It can only open in the absence of external action as the search for roads to it.

It is to be noted that the differentiation achieved by bringing into parallel preserves the basic pattern of reciprocal enervation. All that the bringing into parallel effects is the increase of the intercorrelation of the outputs by rejecting an added class.

### *7. Contradiction and Differentiation*

The lack of regulation to the CR leads to a pattern of differentiation whose steps might be described as ones of successive contradiction. The method of resolving one random search excites others, whose resolution qualifies the first. Indeed, there is no differentiation or narrowing of the range of orders of emitted behaviors as apart from such explicit contradiction. Thus, for example, a bell can be used to condition a salivary response if followed by feeding. This bell response is initially generalized to a wide variety of noises of varying pitch, and no amount of repetition with a bell of the same pitch narrows the response. However, if bells of slightly higher and lower pitch are used, and not followed by feeding, a differentiation in the response pattern quickly emerges. It is deeply significant that differentiation is far more effective than specific reinforcement in locking in responses. The differentiated response will last far longer than the generalized response, though initially reinforced less often than the undifferentiated response.

Paths once differentiated out form sensitive bases for catching new correlations, which the more general undifferentiated motor patterns were unable to catch. Thus differentiation breeds more differentiation.

The nervous system is made up of a set of non-linear loops that interlink. They are non-linear in that they tend to push to extremes. In addition, these loops tend to break up into subloops that mutually exclude as soon as invariant correlates can be found to support such tendencies.

The nervous system pushes the least tendency quickly to an extremum if it can take hold at all. The steady state condition gradually emerges as the most important shaper of CR's as the internal processing becomes progressively more important and in so doing it further intensifies this push to extremes. Thus in the active phase, it may take 100 repetitions to establish the dominance of a given behavior. Once this search is internalized, the dominance, if established once, is established as a repeated ringing loop sequence, so that "once" is enough to take hold permanently. In addition, relative dominances can have their consequences elaborated to other situations by internal processing much more rapidly, than if this elaboration must await the actual occurrence of these situations.

The internal search process is embodied as an internal alternation among loop factors, induced by the series elaboration of consequences. Any factor that leads to an SS, though initially only hit on by chance, is grabbed hold of by the resonance, and repeated internally and so strongly reinforced for future occasions. The steady state condition thus vastly extends the range and sensitivity of the push of only faint, but potentially static, RD to extremes.

The upper rungs of the ladder are in places common pathways to many act sequences. As such the upper loops have a little the character of flywheel factors, with a considerable degree of transferability. Separation in the statistical overlap of common pathways must depend upon the redundancy with which the nervous system operates. In wiring terms, this means that reinforcements cumulate on one loop sequence, but tend to be self-canceling on others.

This cumulation effect is also related to the gradually falling response levels. At birth the motor loops must go off of themselves in isolation. The cortex functions inhibitively relative to the lower centers, as it acts selectively as among the underlying motor factors. For example, the random search associated with a specific grasping action can be greatly restricted by correlates defined in terms of visual field distinctions. As this restriction constitutes a rejection of the majority of such search patterns, it has an overall inhibitive effect. The cortex effects the most accurate discriminatory processing of internal and external sensory inputs, taking, in so doing, the motor factors into higher transference. Hence it can only come into effective action after the child's interaction with its own body is well initiated.

Thus, for example, there will be no correlate between a generalized thrashing and position in the visual field. But once this thrashing has been differentiated into specific grasping actions associated with stopping specific random searches, these specific grasping actions may well find that visual field distinctions are useful in defining simple coincidence effects, further narrowing these more restricted searches. Until the motor pattern is itself rather well differentiated, the sensory correlates it picks up are sure to be inconsistent and self-canceling. Genetics anticipates this functional need. At birth the cortex is inactive, new born babies being nearly blind. It comes progressively into play as the child matures.

The relation of ability to predict ahead to the opening of the internal RS and internal regulation is very central. It is the series elaboration itself which provides the basic source of regulation of drive factors. Because the series elaboration, when enacted, will or did stop the search, its internal representation has connections that tend to do the same, and so serves to reduce the drive level to that minimum needed to still achieve "satisfaction". Thus, the first effect of inhibition is to up the drive level, because it is the series elaboration that holds the drive in regulation.

Although this result may seem obvious subjectively, it can seem rather paradoxical when viewed in external stimulus-response terms. The "inhibitory" stimulus seems to actually intensify the response at first. Tracing back the cause of this subjectively obvious, but externally paradoxical fact to details of the wiring represents a major link between the three worlds of subjectivity, of external stimulus-response, and of internal wiring diagrams.

Notice that this model contains no provisions for "cancellation" of a connection once made. A connection can only be displaced by overriding it with counter-factors, Thus internal alternation leads to a buildup of both facilitatory and inhibitory factors. Alternation is not mere repetition. What then is the effect of alternating? First, it intensifies involvement at the branches of the alternation, spreading its series elaborations over the cortex and so increasing the chance of catching adequate invariant correlates to span this alternation, or establish a stable internal RD, if they are potentially present in some already internalized experience. If this spanning does not occur, continued alternation leads to a stage where a branch of the alternation can go off on its own without benefit of convergence. The drive level rises and a de-differentiation occurs: one falls back on earlier childhood patterns.

Thus the one-way character of the CR principle (that it leads to the making, not the breaking, of connections) in conjunction with the overall structure of the differentiation process, already at this early stage predicts a general characteristic of breakdown patterns.

The steady state condition, and the internal processing that is involved in achieving it, greatly enhances the selectivity of the actually emitted patterns. The basic characteristic of the steady state, its leading to recruitment, or rapidly increasing nervous activity and enactment, is, while implicit in the CR principle, more directly confirmed in a variety of experiments that show that a repeated stimulus applied to the brain leads to an augmenting and spreading response.

Thought is a search for steady cycles. The steadiness implies synchronization of the sub-factors. The search stage implies desynchronization. If the nervous system function is as simple at its core as is implied by the present model, one might expect that this difference would be directly manifest in the characteristic electrical activity of the brain.

And so indeed it is. When in an ‘‘alert" state ready for any possibility, as when trying to interpret sights or sounds, the widest range of random searches comes into play, and the surface activity of the cortex as manifest in the EEG is desynchronized. When working a mathematical problem, the range of motor possibilities is reduced, and we find a relatively more synchronized cortical pattern.

It is order of emission that counts. Unless a sensory difference leads to distinct orders of emission at some point in the series elaboration of the steps it influences, it cannot be distinguished subjectively. It requires a distinct motor sequence, separated off by reciprocal enervation, to form a basis for conditioning at all. Sensory inputs can only be distinguished via the distinctness of the motor loops that they engage. As it takes some minutes of ringing to establish an internal conditioning, only loops, well distinguished by the order of emissions into which they enter, can be used for the establishment of a conditioned response.

The nervous system differs from the usual servo-loop system in that a large number of yes-no feedbacks replace the analog tailoring of one or two feedbacks, to lock in a given pattern. Indeed, the stabilization of a given behavior can be usefully analyzed in terms of the RD’s that specifically reject small variations from it. These rejected paths provide the feedback, when evoked internally, which stabilizes the dominant.

Differentiation takes place in a step-by-step manner, using the underlying primitive unconditioned reflexes as a starting point, and a constant source of regulation, or subordination. Step by step, new invariant RD break up and reform the old patterns of search, while preserving the reciprocal enervation. Rejection, as it becomes more precise can become more widespread and still leave some behavior in an emittable status.

## 8. *Forcing Considerations*

Given the CR principle, generalized to include internal interaction, one has a form so plastic that the problem is not so much to find added possibilities, but rather to discover what aspect of the vast range of possibilities already implicit in the approach is the controlling one.

Mathematical models were once thought inadequate to predict nature. But, in fact, hiding within the class of arbitrary differential equations was the "answer". The CR principle is so broad, and generates so vast a class of possible interactions, as to be almost comparable to the arbitrary differential equation of physics. The problem is to find out "which" in this broad class, not to look outside it, as one once looked outside mathematics. The finding of "which" is problem enough and the formulation of the issue in CR terms is no more an "answer" than the confining our concern to mathematical possibilities gives us Newton's laws - though Bacon's focusing of thought in this direction was of great service.

Given the CR orientation, the general framework of the present answer is forced on one quite rapidly by the facts. The picture is far less confused than most people believe. The experimental results leave room for few possibilities. On the one hand, there is the vast body of evidence pointing to the uniform functional character of all areas of the brain. Areas differ only in the parameters of this common function, as for example in time constants, and ratio of cells of different "type", and in the areas linked by the wires that come and go, etc.

Then there is the evidence that, except in very special cases, no single nerve can fire another nerve. On the cortex, hundreds of nerves must be fired at once to set up any secondary firing at all. This forces thinking in terms of "bundles" that enlarge and contract - a vast source of simplification.

Finally, there is the rough statistical character of the brain's operation. Most refined effects would be unstable and lost in the statistical mess when linked to others, unless they had the simple invariant character implied in the present model. Thus, the random complexity - which looks so forbidding at first - is in fact a source of great simplification of the logical possibilities when approached with some knowledge of statistics and a realization of how fast weakly correlated links are self-canceling as they compound, if independent.

When we attempt to reconcile the known facts or principles in a self-emergent causal framework limited by the above three general considerations, these known principles are quickly seen to imply far more than is generally supposed.

For example, the larger number of cells needed to fire off any further cells forces thinking in terms of bundles that expand and contact as they take hold. The rapid self-cancellation of non-invariant or weak correlations as they compound, forces thinking in terms of simple repeating coincidence effects between ringing loops. The uniform functional character of all areas forces us to look to the structure of the environment, or of the inputs themselves, as the source stabilizing internal structure.

### *9. Brain Centers*

Special brain centers do not represent a violation of this simple overall functional picture. Rather they reflect the correlated nature of the environmental inputs, and their breakup into such classes for special processing as our model implies. Certain centers are concerned with turning, rising, etc. Certain areas are concerned with spreading the final output rhythms to catch special coordinational regulation once the act is "decided" on (the cerebellum).

The common reticular formation, in which the lower centers are in a sense all imbedded, is concerned with the common functions not associated with specific centers, such as reciprocal enervation, and timing. The emergence of the special timing function is to be regarded as an indirect effect of the contribution to ringing or the SS which such timing brings about. The correlations exhibited on stimulating the various centers reflect the lower order correlations or average correlations of that center.

The interrelation of the centers and the unconditioned reflexes represent merely a genetic pre-encoding of the effects of correlation pressure, or the emergence of dominant correlates, which pre-encoding helps accelerate the emergence. Were it not merely a pre-acceptance of the implications of the laws of operation of the nervous system, the effects would be rapidly self-canceling.

The pattern of centers and their interlinkage indirectly reflects and confirms these laws of operation of the nervous system, as applied to the special class of correlates which our present environment represents, just as the orbits of the planets indirectly reflect Newton's laws as applied to certain initial boundary conditions. The more detailed discussion of the interrelation of the centers, and the derivation of these relations from correlation pressure as applied to the available class of correlates, is beyond the scope of the present paper.

## *10. Logical Flow Diagram of the Processing of Correlations*

In Fig. III we have an outline of the earlier discussion in the form of a logical flow diagram of the processing of correlations which, as a parallel calculator, the brain picks up.

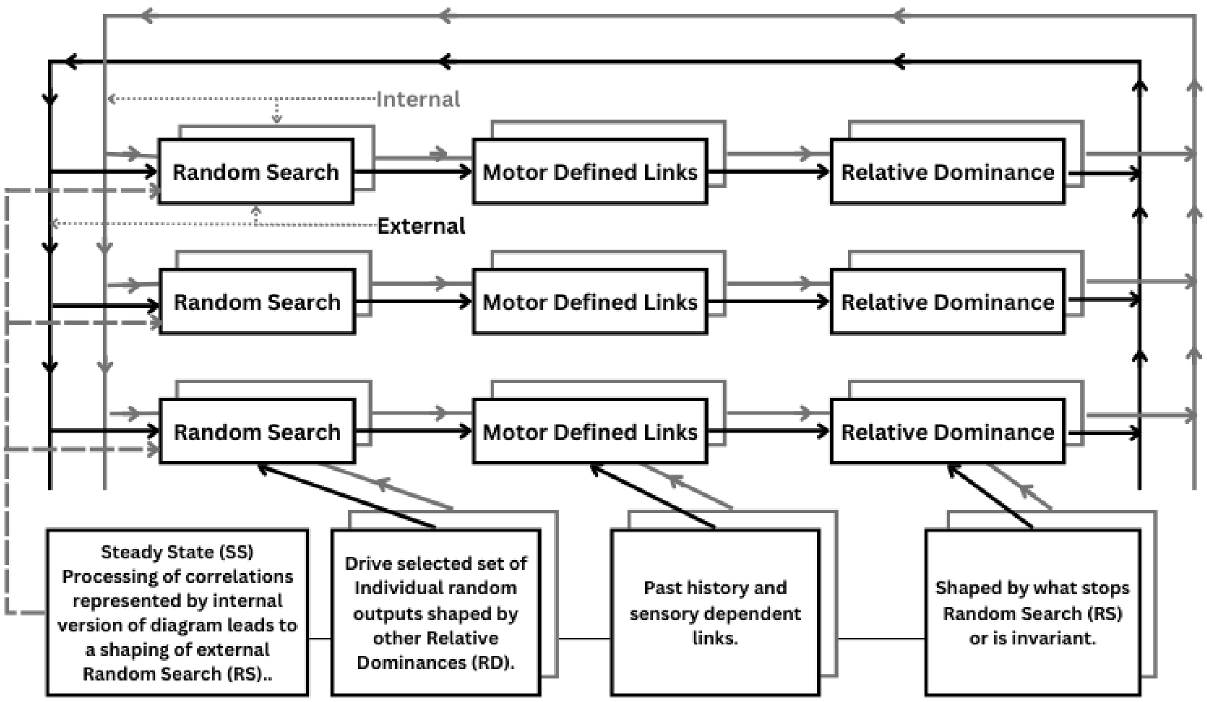



*Figure III: Logical Flow Diagram of the Processing of Correlations*

The diagram is not a model, any more than physics is a model of the world. The factors that enter into the conditions of stability of a given behavior, like the factors that enter into the shaping of a bridge, are highly varied. The narrowing in the river, the local town being where it is, the bribe to the city council, etc., ail enter in as essential factors shaping the bridge where and as it is. To try and combine all these factors in one model would be very confusing rather than helpful. In practice it would be entirely impractical. Now the nervous system has the symbolic structure of a fore-shortened model of the world. As physics in explaining the world only provides a systematization for the compounding of specific correlations out of the unqualified universals of the calculus, so too the best we can do by way of explaining the nervous system is to develop a systematic procedure for analyzing the changes or specific narrowings in the order of emitted behaviors, and translating this analysis into underlying wiring diagrams adequate to explain this specific narrowing causally. In this process behavior is analyzed into its smallest motor details, just as a golf pro or piano teacher must.

If we look at the overall pattern of the theory, we see that it is a theory of learning. But learning is not a part of life, but the whole of life. What is not learning, is nevertheless encoded as a foreshortened recapitulation of earlier learning. Any emitted behavior of consequence implies an earlier learning process which shaped it up. The control variables lie in this educational phase. All the rest of life may be viewed as but the blind mechanical consequence of adjustments established in these educational phases, or else new grist, that feeds back in and reshapes these educational phases.

The control variables lie in education, in our intellectual convictions and verbal models. Thus what might at first seem a limited point of view directed towards only one aspect of human behavior, learning, comes on closer examination to include all aspects.

This same sequence repeats itself in examining the specialized attitude inherent in the focusing on order of mutually exclusive acts, in so far as it is a limitation, it is a limitation reflected in the whole character of the learning process, and a highly substantive verifiable limitation. Conditioning is motor conditioning, basically. Sensory factors only interlink motor loops. (Here we are using the term "motor" in a generalized sense which includes salivation, etc.) In order that distinguishing simple CR coincidence effects be available between distinct loops, actual order differences in emitted behaviors must occur, either externally, or in their internal foreshortened representation.

If a loop is not internally differentiated from another loop to which it is to be linked by mutual exclusion effects and order differences, it is functionally the same loop, and hence facilitatory or inhibitory collaterals cannot be spoken of as existing "between" them. It is known that loops are needed to establish links since recurrent ringing for ten minutes or so is necessary to preserve memory traces. In reverse, if such simple coincidences defining an effective stable RD are repeatedly present in the past history of a given brain, the associated RD will take hold eventually if the associated range of freedom is held open and not closed against this resolution by other stable RD.

Thus we are positioning wires relative to the pattern structure of the differentiation process, it is an indirect form of functional positioning, in a model only implied, even as is the explaining done by physics.

Now the pattern structure has, of course, analog aspects. The mixing of analog and pattern effects (like the mixing of a subjective projection with the syntax structure in studying the foundations of mathematics) leads in many cases to an obscuring of the basic simplicity of the overall operation. The analog aspects of the CR interactions are often self-canceling, as the shape of the sand grains in the sand castle, or the mass of individual atoms in certain calculations of gas pressure, so that a large number of central effects can be predicted on the basis of this rough abstract model, without considering any of the underlying details, or analog effects. A few of these will be discussed in the next section.

Another way to view the structure of this method of analysis is against the backdrop of old philosophical arguments which claimed such analysis was impossible. Thought, it was roughly and variously said, could not be made objective, because of the inherent subjectivity of our observation of it. Such a situation with cyclic interdependence exists also in the case of planetary orbits but does not prevent their solution. Because one thinks about one's thinking process does not mean one cannot also build a model of so doing.

What we have in effect done is resolve the paradox by presenting a model of the cyclic interdependence itself and then proceeding in stages, as in a self-consistent field calculation, to get the needed answers. Most people expect too direct and too automatic answers, and so block themselves in their search. They often do not see how indirect or merely implied construction is often quite adequate, or can be made so by a variety of special devices tailored to the given Issue in hand.

We may now review our earlier results, following through the logical diagram (Fig. III) in more detail. We might start with some set of random search (RS) factors. These sets are highly individual, being set by drive factors, as from the hypothalamus, as well as shaped by the sensory inputs, pains, past history, etc., as is implicit in the logical feedbacks from other parts of the diagram. Indeed the analysis into RS's is a highly flexible one, the choice being adapted to the specific narrowing or ordering of behaviors to be explained. The RS's overlap in many ways, and the division into RS's could be made in many ways. It is comparable to the two-body analysis of physics. This ambiguity, in so far as substantive, reflects a real ambiguity in possible methods of conditioning. Many wiring diagrams, or methods of learning, lead to the same final specific behavior.

Now the RS factors are interlinked on the basis of one's past history and these interlinkings become themselves sensory dependent, in so far as they are correlated to sensory factors, as is shown schematically in the next box.

These random search factors, as thus intercorrelated by interaction with the environment, are broken up and brought into parallel via the establishment of relative dominances (RD's). In a sense we bring the branches into parallel to find the RD. But nearly the reverse is also true - since finding the RD lets us, in a sense, keep the branches in parallel. If no RD is found as among a set of competitive possibilities, then they cannot be long considered together at once - the response level rises, and each must on its own find convergence or facilitation enough to engage its associated act and exclude others. The emergence of an RD is thus essential to "keeping in parallel", in the sense of eliminating the competitive aspect among these mutually exclusive factors, so that they may be permanently excited together in any combination, yet funnel into a common emitted act.

This operation of establishing an RD we may regard as the basic operation of the brain as a parallel calculator. The dominant path is defined as that which stops the random search, or narrows it.

Now the result of establishing a specific RD is a logical feedback, reshaping the initial random searches. Indeed by splitting them up, it creates new, more sensitive bases from within which to catch the intercorrelating effects of sensory inputs. This cyclic refinement pushing towards ever more invariant correlates, constitutes the differentiation process.

Patterns are locked in via the systematic rejection of competitive alternatives. This indirect form of conditioning already greatly simplifies the problem of finding adequate CR universals out of which to compound observed behaviors.

The reconciliation of RD's emerging from different random searches pushes us towards ever more invariant correlates, until one is rejecting a large class of paths without self-paralysis and predicting several stages ahead. It is then that one begins to internalize the random search process itself. Internal processing occurs until the series elaboration, or successors of a given “next" act, ceases to unstabilize that act, and an internal repetition or steady state (SS) becomes possible. At this stage emission occurs or is “decided on", and interior attention shifts to some other random search which involvement in the previous RS had inhibited out, via effects of reciprocal enervation as generalized in the model.

Now this internal alternation can be broken up into random searches in complete analogy to the external searches, and the external logical diagram repeated on an internal level.

Thus the internal historical sequence of loop engagement tends to be linked together, just as the corresponding acts they represent were when enacted. Also internal sensory factors take these internal loop sequences into higher transference, or intercorrelate them. Finally internal RD are established, as that which stops or narrows internal random search and contributes to the SS. These internal RD have then an internal logical feedback, reshaping internal random search.

This internal processing is roughly what we call thought. Its upshot is to greatly narrow the external part of the random search. Only such act sequences as can meet the internal SS condition will be emitted at all.

The sensitive SS shaping is the key to understanding how we can compound the wide variety of emitted behaviors out of simple universals of a CR type.

The stopping of the internal random search leads to emission of a behavior from the internally searched-over class. The stopping of the external random search ends emissions from the associated class of behaviors. The act is emitted (or "decided on", awaiting only the special circumstances of emission), as soon as the series elaboration ceases to upset the symbolically "next" step in question.

Internal processing enormously extends the intensity and range of thrashing, searching for ever more invariant correlates, or correlates that are more often reinforced, or more often contribute to a narrowing of the search. Of course, as an internal link or response, any established correlate is a universal. When we speak of the degree of invariance we have reference to its reinforcement, or some measure of its success in narrowing random search.

## *11. A Summary*

Internal thought is thus embodied as a set of inter-facilitating and inter-quenching non-linear loop circuits, organized by internal timing effects.

These internal loop processes, or "intermediary processes" as D. O. Hebb calls them, have been made concrete in a variety of ways.

These loops correspond to underlying motor factors, or classes of such factors which they serve to help engage when sufficiently activated.

Sensory factors do not have independent loops of their own, except in so far as they take over underlying motor ones as by intercorrelating them.

The sensory factors only serve to interlink motor factors. Such intercorrelation can often appear as "inducing" one response from another. Drum beats help force present, states or loops on to extremes and so excite successor states or loops at their associated rates, etc. They consequently facilitate motor sequences having or using these characteristics or intercorrelations. These loops are organized in parallel patterns which are "focused" to choice of act by RD's, defined as that which narrows the random search.

These loop linkages are pattern-oriented. Only factors effecting the order of emissions can be internalized. The separation of the pattern elements is defined by reciprocal enervation. Unless such elements stand in distinct sequences or orders with respect to relations of excitation and inhibition they are not distinguished, and so cannot be used in turn to distinguish a sensory input.

The brain has a wide class of random interconnections whose more invariant forms are pushed to the surface by the internal random search.

The generalized principle of reciprocal enervation, and CR principle, as extended by the SS concept, provide a basis for explaining the stable self-regulation and self-emergence of more complex patterns in correlated environments which constitutes learning.

## II. Some Applications

We will now consider a variety of applications of the model that can be made, for the most part, without reference to more detailed analog effects, or the role of distinct centers. These applications will range from the prediction of consequences of excision of brain parts, to subjective evaluation of sensation, and psychoanalysis. Some alternative methods of viewing the model (comparable to alternative formulations of mechanics) will also be briefly suggested.

This is no systematic coverage, rather merely a half random scatter of effects designed to suggest some types of application to which it can be put even in this simplified form, without any detailed discussion of the centers or cell types, etc.

In the following we shall present a number of effects as "predicted" by the model. These effects were, of course, known before the model, and were guiding factors in the determination of its features. They are presented as predictions of the model to help emphasize certain of the peculiar ways in which types of explanation afforded by the model restrict patterns. A variety of predictions and experiments suggested by the model of an as yet untested character are presented in the longer studies now being rewritten.

### *1. Brain Stimulations*

What type of "effect" might one expect on stimulating the brain? The model implies that the elementary reflex components, associated with primitive responses of locomotion and grasp are repeated in the higher loops, and serve as the starting points of further differentiation.

Stimulation in that it fires all or a large part of the cells in a given area indiscriminately could only be expected to reveal the lowest order correlates of that area. Thus we might expect to elicit fragments of coordinated motor responses, or synergic muscle groups. Also, since the reciprocal enervation runs through the entire brain, strong enough stimulation at one point on the cortex might be expected to inhibit the other areas. Both these effects are observed.

The simplicity of the organization of the human calculator is revealed in such elementary experiments. Most complex calculators have successive stages isolated from each other, and stimulating a few hundred wires at once is not likely to have coherent effects. The peculiar nature of the class of effects observed represents therefore a confirmation of the proposed principles of operation. In addition, the schematic wiring diagrams of Fig. II are of course very simplified versions of the actual observed wiring patterns. It is hard to imagine a machine with this simple pattern of wiring and responses, working on any other basis. At very least these stimulation experiments reveal the centrality of the basic functional motor patterns and reciprocal enervation in the organization of the calculator.

### *2. Brain Excisions*

What type of effect might one expect to result from brain excisions? The model implies a uniform function to all parts of the brain, a given area differing only in the parameters of that common function, and the specific other areas to which it is linked. Hence, unless final output areas were cut into, one might expect very little to result from the removal of small sections of the brain, and such little as does result, to be easily compensated by a takeover of the given function by other areas. This is in sharp contrast with what would happen if a small section of a radar set were taken out, or of a typical calculator.

If we consider the great redundancy with which the brain operates, and the involvement of wide areas of the brain in all responses, one might further predict that no specific memory or IQ loss would result from removing small brain sections so long as certain crucial areas were not cut into. The capacity required for establishing a given reflex pattern is far greater than that needed to merely maintain it, since once established, foreshortened methods of conditioning quickly take hold, making use of the more complex initial CR's to stabilize them. Hence, established and simplified reflexes with their great redundancy would seem unlikely to be effected by specific excisions, which is indeed the case. This would appear to afford a rather powerful confirmation of this simple overall functional picture of the internal processing of the CR's via the SS, with no special internal mechanisms. Though it is easy to suggest special internal machinery that will solve any specific problem, it is very hard to find any that can at once have pieces removed anywhere without breaking down, and be, as a "machine", self-emergent via a learning process - for our complex learning is not genetically encoded. These simple elementary experiments provide, therefore, a much more powerful confirmation of the present approach, and a more powerful critique of many ingenious but inadequate attacks than might appear at first.

How can the interior of the calculator be so plastic and still hold some guiding structure or principle of order? The answer lies in the recognition that the internal structure or principle of order is derived from the environment itself. The brain quickly breaks down when not fed properly structured inputs. The stability of the internal structure depends on that of the external environment. Only thus could the great internal plasticity be compatible with or lead to internal ordering. This internal order emerges as the internalization of an external order, implicit in the interaction with the environment.

When this key to resolving plasticity and order is combined with the earlier evidence on the simple central organizing role of the elementary motor patterns, and reciprocal enervation, the solution as here presented is very nearly forced on one.

### 3. *Processing of New Correlates*

The self-emergent character of the major portion of the internal structure is a powerful source of guidance, a test that few models can meet. Certain details of the pattern of this emergence, as implicit in the present model, can be tested in a variety of ways.

Any new internal correlate is apt to upset the old RD patterns and so initiate a rudimentary random search. The old centers are no longer balanced out with this new factor present.

Now internal random search, as we have seen, augments involvement at these points until either the drive level is raised, or the alternation predicted out via the isolation of adequate spanning RD in some form. The alternation may gradually take over the whole brain, pushing for adequate resolving RD, and involving more and more interlocking random searches in the process. This search of course greatly enhances the chance of finding invariant RD. Once adequate RD are isolated, a re-condensation occurs. The elaborate overall RD is used to re-condition the underlying foreshortened RD associated with narrower ranges of freedom.

Thus at first in piano playing we hold our fingers in certain positions "self-consciously", later this self-conscious holding conditions an “instinctive" holding which does the same thing using far less of the brain's capacity. As in solving a puzzle, when we find one thing that must hold regardless of other things, we can use this fact to simplify and help solve the many sub-problems.

Now this sequence of expansion and contraction of the range of nervous activity associated with a given correlate in process of its integration should be a highly characteristic one, immediately manifest in the patterns of electrical activity of the brain. The theory identifies the basic activity with the motor streams and motor loops themselves, so there is no place for a sub-structure or the complexities of yet more primitive brain processes to obscure such effects. By way of contrast, in television the information is encoded on a carrier wave and the details of this wave and the encoding process override and obscure the details encoded. The electrical activity in a TV set has no simple relation to the content encoded, as is the case in the brain.

These expansion and contraction effects are observed in a wide variety of forms. For example, a repeating tone has its own characteristic repetition frequency, by which response associated with the tone in different areas of the brain can be identified. Thus the spread and amplitude of response to the tone can be measured as a function of time. There is a very characteristic initial rise and spread, followed by collapse in this frequency component of the electrical activity of the reticular formation or the general matrix in which other centers are imbedded. This characteristic spread and fall lends itself to an interpretation of this model of brain operation in a sensitive way.

The rhythm itself under investigation, or the class of motor factors it takes in transference, is spread, unobscured by indirect machinery or isolating stages such as is often implicit in special models adapted to reproduce isolated brain responses.

Another example of the same type is the change in electrical activity of the brain as a manual response is learned. In early learning stages the whole brain is involved in the electrical disturbance associated with the manual response. Later, only the hand area is involved.

Such contraction may be viewed as an example of the progressive simplification of encoding of a learned response, using the initial more complex encoding to condition or set up the coincidences needed for the simpler encoding. Such a contraction does not imply any special transfer or simplification process not implicit in the generalized CR principle itself. Once a behavior is set up in more elaborate indirect ways, a wealth of simpler internal conditioning effects emerge to foreshorten the internal random search in endless ways.

### 4. *Threshold Effects*

Unlike most machine models, the present theory implies that the whole brain is involved in the most elementary response, since factors are integrated, that is, enter stably into a determination of significant calculating machine activity, only in and as they effect the order of emitted behaviors. This has a wide variety of potential implications.

This should mean, for example, that a sensory input which served to interlink certain classes of motor factors would be the more easily responded to the less such response as the sensory input induced disturbed underlying motor factors, or the more nearly it fitted into them.

Now this is a rather strange characteristic for a typical machine, in which the sensitivity of detection stages usually are not a function of how big a change in the output pattern such detection will imply.

However, the link of perception to response, and the involvement of the whole brain in response implied by the model makes such a strong link between threshold and mental state clearly implicit.

A wide variety of experiments confirm this implication. Lines and other patterns that "fit" have a much lower threshold for being observed than those that don't. Expectation of the class of patterns to be observed also lowers threshold, etc. These effects go a long way towards directly exhibiting the simplicity and directness with which the underlying representative motor cycles are excited or linked by the sensory inputs.

### 5. *Caught in Stop*

The success or workability of this model is closely linked to the character of the random searches excited. They must be "solvable" by a series of progressively better approximations, based on simple internal coincidence effects, in such a way as to open out into the main life problems. Most random searches have no such future. Indeed most searches lead only to madness. The random searches for food provide a base structure which the sexual involvement can then open further. Sexuality provides a reinforcement which forces us to internalize the bodily attitudes of others as if our own, so that the emitted act must satisfy both people. Random search opened by this method is of a type most apt to catch significant invariant correlates. The search is narrow, limited to an alternation as between the viable attitudes of two people. Since both branches are viable in some context, the focus is apt to be an especially productive one in catching invariant correlates. Other classes of motivation, such as pain, excite random searches so general as to lead to RD with little future, that is, RD that cannot be further differentiated. The harm caused by excessive use of such motivation has been well brought out by Skinner.

What should happen to a person if this internal wiring was radically reorganized about some random search, such as pain, with no future? The implication of the model is clearly that death should result. The whole internal wiring is subordinated to the principle of reinforcing what stops random search. If the random search associated with pain were not clearly subordinated to that due to hunger, etc., the basic rewiring it would effect could be nothing short of lethal.

This is dramatically confirmed by catching animals in what is called "stop". An electrode is implanted in areas whose stimulation is very painful, and the animal trained to push a button to avoid being shocked, perhaps several times a minute. After a few hours of this the animal dies.

Pain represents a type of induced internal random search and consequently leads to an internal rewiring. Pleasure, however, represents a stopping of the random search and hence stops even the spontaneous normal rewirings of curiosity. If an animal had an electrode implanted in his brain in "pleasure" areas that stopped random search, and was trained to push a button to "start" stimulation, and so stop or reduce the RS to an extreme minimum, no such negative effects as are associated with the earlier caught in "stop" would be expected. This implication of the model is indeed confirmed. Animals caught in "start", pushing the button to obtain (not avoid) stimulation, can continue for days (if fed) with no adverse effects.

These simple experiments expose the centrality of the role of the RS in defining internal wiring. They confirm in a dramatic and direct way how closely the internal wiring is linked to the class of random searches being stopped, and so directly exhibit the central organizing position of the random search as implicit in the model.

## 6. *Transference of Learning*

If we examine the model, we can see that no special machinery to transfer learning from one area into another area is present, except such as is indirectly implicit in the CR principle. Nevertheless learning in one hand as of a tap sequence to achieve reinforcement can be transferred to the other hand in a small fraction of the time involved in setting it up in the first hand. What is the reason for this? Does it represent a violation of the limitations (e.g. the absence of special gadgetry) implicit in this model of brain operation?

The upper centers and loops have a little the character of flywheels which can be engaged in a wide class of motor patterns. In addition, the common embedding of all centers in the reticular formation, and the spread of motor rhythms by that formation means that in teaching a pattern to one set of muscles we have in a sense taught it to all sets of muscles at once. It is not so much a transference of ability which is involved in the class of experiments mentioned above, as the use of common pathways (esp. the reticular formation) by all motor processes, so that the training of one becomes, essentially, the training of all.

The absence of any transference of learning (except that indirectly implicit in the CR principle or in the use of common pathways) can be directly confirmed.

We have simply to devise an experiment in which no common pathway is used in two similar training procedures. This is a little harder than it sounds, but can be done. Thus the optic nerve can be so cut that each eye only stimulates its own side of the brain, leaving the subject blind in half his normal visual field. In addition, the major cross connection bands between the two halves of the cortex need to be cut. These cross connection bands intercorrelate the two sides of the brain and lead to a transfer mechanism similar to that indirectly implicit in reticular function, so that the training of one side trains the other at the same time. As such, it does not represent a special transfer mechanism, but merely one indirectly implied by the CR principle, and the symmetric character of the body which gives rise to general low order correlations between sides. When this band is cut and the animal is trained to recognize patterns with one eye, it is found that this training does not shorten the learning time for recognition with the other eye.

The absence of any transference mechanism, and the interpretation of such apparent "transference" and simplification as does occur is due to the use of common pathways and the CR principle, help confirm this simple picture of brain operation. The special internal machinery implicit in a true transfer mechanism is not present. Transfer of conditioning exists only as an indirect effect of other factors.

## 7. *Vision*

### a. Higher Motor Takeover

This model predicts that the visual gestalt, or visual awareness, is only built up as the gradual takeover into higher transference of underlying motor patterns. This motor origin of what, at first, seems unrelated to motor factors, serves as a sensitive test of the present model.

This process of gradual motor takeover by the visual field is confirmed in a wide variety of experiments. When children are first born the cortex is essentially out of operation. The cortex functions inhibitively relative to the lower centers, and at this early stage the child is investigating its own body, and each isolated motor loop needs to go off with a minimum convergence. Thus the initial coordination is built up in a semi-blind state.

The first takeovers by visual factors lead to responses almost indistinguishable from touch. The child reacts to the sight of the object as to its textures.

A few people have been blind at birth, and only gained their sight later after they could verbalize. Watching the way in which these people learn to use the visual field confirms in many ways this general picture of the visual function as one of takeover of underlying motor factors.

Long before they are able to recognize objects in the visual field they are able to use bright spots or edges in it to selectively modify their behaviors. They can, for example, bring the bright spot into the center of the visual field. They can also tel! whether their eyes are moving in the direction of a line or across it. Elementary motor responses are thus controlled or correlated to visual factors. Later they use these motor links to recognize shape.

Presented, for example, with a card having four spots and asked "how many"? these people will not know, but they can use the spots to coordinate head movements and then count the number of times they move their head. By this process they can distinguish the number of spots.

Similarly, at first they cannot distinguish a square from a circle. But if they turn their head along the line, they feel the bumps in the square that are not present in the circle by the jerk in their movements. Later they can feel these bumps without actually moving their head, and might call the square "the bumpy one".

The associated acts or eye movements have been internalized, and some unique sensory combination has been found to take their associated loops into higher transference. The "bumpyness" is then excited and felt without an associated emission. When we consider the wide variety of sensory inputs created by the active probing implicit in small eye movements, it is only too easy to construct or isolate sensory factors or combinations of factors necessary to take the associated internal motor loops into transference. Preinformation that helps limit and guides possible induced motor organizations, further greatly simplifies the needed encoding or needed distinctions.

Many other experiments reflect this basic motor character of visual field organization. To touch an "illusion" that was misintegrated, rapidly reorganizes it, so it is "felt differently". Tiring the muscles on one side of the body shifts our sense of the vertical in a field where there is no other source of reference.

### b. Wholes

Factors are integrated subjectively only in and as they narrow a RS and so effect the order of emitted behaviors, and form part of the parallel structure entering into the definition of the present act. It is pattern alone that counts. When we consider how rapidly a geometric series expands (or contracts), this appears as far less restricting a limitation than it might seem at first. A few stages of such pattern elaboration can provide as accurate a discrimination as anyone could use. What is not locked in in this way as pattern, and is free to float, subject to continuous variations that are a function of the reinforcements, is something subconscious and of no emotional significance to us, in the main.

Now the embryo of the visual gestalt concept lies in the set of parallel factors "focused" by RD into a single choice of act. We understand the room, via the wide field of possibles it serves to reject, focusing us into one present act. The rat needs to run around the room before it can eat quietly. Certain qualitative aspects of this parallel structure manifest themselves in rather striking subjective phenomena and help explain them.

Since one is dealing with an ordering rather than a continuous phenomena, when he considers subjective effects, one would expect pieces of visual gestalts to appear and disappear as wholes. The complex structure of these reflect sets of factors which combine together in the setting up of complex RD.

Such effects are indeed observed. Even the subjective sense of a continuous color gradation is broken up into distinct steps, or bands, reflecting the principle that a sensory difference has no subjective counterpart till it leads to a distinct ordering. Differentiation occurs only via contradiction, and associated distinct motor patterns or sequences rejected.

In interpreting the subjective character of the visual experience in these terms it is important to realize that we see in any given instant far less than we realize, that is far less than the grammar of our way of talking seems to imply. The complexity of perception exists chiefly as an assurance that any one of a wide variety of complex details can be (or have been) checked "at will". Our knowledge of "Maxwell's equations" exists less as an immediate awareness, than as a confidence that we can behave or respond in ways that solve problems if called on to do so. In a somewhat different form this is also true of the complexity of our visual awareness - though here problems are solved at such high speed that, unless we observe ourselves very carefully, we will not realize how little we "see" at any instant.

The visual field can be thought of as a vast array of potential and actual parallel flywheel factors, most of which are not used in determining the present act. Small sub-sets of the sensory inputs from the eye are constantly entering into or competing for awareness, and driving out others.

Visual hallucinations are like the waves of the sea. Though physics can never predict the waves of the sea, their general pattern and character can be predicted, and the specificity that is left is recognized as irrelevant. This same is true of visual hallucination. The occurrence of such hallucinations helps confirm how completely subjective character depends on independently stable motor patterns taken over, and only in secondary ways upon the nature of the sensory inputs.

### c. Average Transference

This simple model implies that sensory inputs come to have definite motor tendencies and so a subjective character, only via their average function in correlating or inducing one type of motor sequence more than another. The simplicity and immediate forcefulness of this is illustrated in the subjective sense of greater nearness of lower objects, and brighter objects, or the feeling of jutting out when there is a dark line ("shadow") below, etc.

This type of observation helps confirm a general implication of the model, to the effect that these primitive motor tendencies are not due to special internal machinery, but are merely an indirect effect of the CR principle. Low objects are in general nearer, as also are brighter objects. Things that stick out cast shadows below; holes, generally, have the shadow in the upper part, etc. Hence, low objects tend to reinforce motor patterns associated with nearness, etc.

Once sensory inputs come to have such motor aspects, they can be relied on for further conditioning, but they are not, except perhaps in a few very primitive respects, associated with genetically defined factors. This is well confirmed in the dramatic reorganization of the visual responses that can be effected in a few weeks with special glasses, inverting images, etc.

d. Center Balance

Another class of effects comes under the heading of center balance. The degree of excitation or sensitivity of a center is according to this model regulated by what most contributes to the steady state. There are a wide variety of feedback mechanisms that can shift the level of all inputs at almost every stage of their processing. Small variations in these feedbacks, like external motor acts, get reinforced or not according as they lead to a local ringing.

Now as the subjective effect only depends on the motor patterns taken over, not on the inputs, shifts in balance needed to accommodate inputs should give similar subjective effects on wide classes of inputs. This is dramatically confirmed and illustrated in the Land effect, where three shades of nearly the same color give subjectively the effect of a full spectrum. It is also illustrated in many other phenomena, as where a sense of pitch or of roughness or straightness is radically modified by immediately previous experience. Center balance is adjusted for an optimum evoking of the full range of underlying motor gestalts, and this may lead to radically different subjective responses to the same input depending on the immediate past history for which the SS adjustment to optimum center balance was made. If very rough objects have recently been felt, rough objects feel far smoother for example.

## 8. *Absence of Special Brain Machinery*

We see that in this approach, no special local machines are implied, A local machine is, in effect, gradually built into, or specified in each area by correlation pressure (the ability of more invariant correlates to displace others), the general SS action, and the character of that very special class of correlates there available. Thus the visual cortex

has cells whose dendrites extend preferentially in different directions, and so respond preferentially to different classes of inputs. Like the difference between eye and ear, the difference in direction of the dendrites leads to cells firing under different circumstances. Hence, they enter into a different class of correlates. But that is all. The CR principle as here elaborated, appears potentially adequate to explain the nature of the machinery that is indirectly built in. There is no need to assume any special added principle.

Indeed such genetic pre-encoding as exists can all be subsumed as a preacceptance of the results of SS processing which pre-acceptance accelerates differentiation. If actual interaction with the environment did not in effect re-create and reinforce the genetic pre-encoding, the effect of the pre-encoding would soon wash out. There is no need for or place for any other principle or special machine in organizing brain operation.

Thus the cell types, the position and interrelation of the centers, etc., can be viewed as internal reflections of the basic classes of correlates to be processed. Visual correlates which distinguish preferentially distinct directions in the excitation patterns are especially apt to be significant. Such a distinction in the sound analyzer or parts of the temporal lobe where the auditory inputs are finally projected is apt to be meaningless, that is, catch no invariant correlates and so not be reinforced. Accordingly special cells which are direction dependent appear in the visual areas and not in the sound areas. Again the number of nerve cells involved in a given muscle's cortical projection reflects the degree of differentiation of that muscle's movement in thought processes and coordination. The eye muscles, throat and hand have large projections, the foot small, etc.

These endless detailed relations between the structure of the class of correlates to be processed, and the internal organization of the brain, represent a confirmation of the present model whose internally stable structures are viewed as basically stabilized by interaction with the environment, and reliance upon the stability of this environment, via reliance on the stability of our patterns of interaction with it.

## 9. *Logical Depth*

The search to find invariant correlates that narrow the RS and help span the field of possibles is far easier than might be imagined, when we realize that all that is needed is an indirect conditioning by stages relative to the rejected field of possibles. In addition, this class of rejections is greatly extended and systematized by the internal SS action. There is also the point that a selective active probing as distinguished from passive response, can help in creating classes of invariant correlates, in ways which greatly extend possibilities, and simplify encoding.

The logical depth of the world order is surprisingly thin. Despite the multiplicity of forms they are all subsumed (in a logical sense) by a few universals of physics.

The encoding in the brain parallels the logical depth rather than the multiplicity of the world. A brick wall is encoded as its principle of repeated symmetry, in and as it effects motor patterns, not as a photographic reproduction of the wall. Preinformation makes the eye able to see and the ear to hear far more than is there to see or hear, given a few hints.

This wide disparity between logical depth and the multiplicity of forms, is basic to the success of the human, or parallel, calculator. Alternation always brings into the open spanning universals, somewhere, in a large society. Once found, imitation quickly propagates them throughout the group.

This recognition of the wide disparity between the multiplicity of facts, and logical depth, helps us to understand how it has been possible to isolate invariant RD in step-wise fashion; to ever further narrow the random search by this combination of a wide class of attacks, a wide class of random interconnections and imitative propagation of the dominant.

## 10. *Decay Channels*

The brain can be viewed as a sort of compound atom with a wide variety of allowed decay channels. It serves to convert inputs to a choice of outputs. Any input, in that it ups the probability of one decay over another, has motor aspects. Crossword puzzles are a good example of the sensitivity of this effect.

The isolation of the special paths in the field of possibles that serve to stop random search is the ultimate foundation of the clear-cut reciprocal enervation that organizes the brain. Only quite special ways of acting open boxes or cut wood, etc., and all the combinations that are “part way” between “opening the box” or “cutting wood", flop completely and greatly expand, rather than reduce random search. Each step of parallel calculator operation, as the establishment of an RD, preserves this reciprocal enervation, only further subdividing earlier paths.

From a decay channel point of view differentiation keeps restricting the possible decay channels, but as it does so the remaining ones become further series elaborated, or more complex, so that the total number of distinct ones increases as they are refined or restricted, rather than decreases.

The problem is to find stable forms of universal negation, or RD, that do not blanket out all response, do not raise rather than narrow random search. The points in the human repertoire where heavy differentiation can occur are quite limited. Eating and sleeping are much as they were 10,000 years ago. But the points that can differentiate hold the center of attention, and power enough to transform the world order. It is what opens that orients, not what does not.

### *11. Lock and Key*

The above view gives rise to the larger question of how so many motor factors can overlap in such a simple direct way involving the whole brain, without so interfering as to destroy the possibility of coherent thought. The key to understanding this is what one might call the lock in key effect. Unless nerve firings are properly timed so as to cumulate, they wash each other out. This "proper timing" and “cumulation" may apply to only one channel, while hardly fitting all the others. The great redundancy of the information on which human response operates, combined with a few elementary considerations from statistics, shows how easily such "statistical separation" in the overlap can be effected by “lock and key" effects, despite widespread interference.

FM sets operate on a related principle, using excess bandpass to nearly completely, eliminate noise.

Most nervous activity is irrelevant to present awareness. Most areas of the cortex can be fired off with no conscious effect. The need for cumulation helps us understand how this **is** possible.

Again inputs can modify the probability of emission without our being conscious of. them. The decay channel model, in conjunction with such effects helps dramatize the simplicity with which CR universals compound via the SS condition to define the act. They represent a sensitive test of the model. Most machines involve distinct isolated stages, with no cross interference, so that such effects could not be present.

### *12. Color*

It is well known that characteristic rhythms condition the associated state of mind. If the sleep rhythm is forced in the midline nucleus of the thalamus, sleep is induced, though almost any other rhythm there enhances wakefulness. This is a nice example of the depth to which the lock in key rhythmic aspect of the CR principle organizes the brain.

Thus any characteristic rhythm may be expected to induce or support that form of center balance, or those attitudes, under which it would be spontaneously emitted.

This is especially true when a factor is at the center of attention, for then its characteristic rhythmic response is amplified and spread over the whole brain, in process of acting out the random searches it induces. In states of mind related to those induced by a given sensory input or rhythm, its recognition is easier, or its threshold lower.

The prediction that a rhythm may be expected to induce or support or facilitate the class of attitudes under which it would be spontaneously emitted is well illustrated in the subjective character of colors.

Vision depends heavily on cells that fire when the light goes either on or off, sometimes called on-off cells. As an edge passes over these on-off cells, they respond, hence edge effects are especially important in organizing the visual field. Small vibrations, too small to notice, play an essential role in vision, as they move edges across several cells. . Mechanically holding the eye still for a couple of seconds, so as to really stop these vibrations, causes images to disappear.

Granit has shown that one aspect at least of the color encoding lies in the rapidity of rise of nervous activity of the off-response. The rise is rapid for red, and several times slower for blue.

Now this model implies that sensory factors have a subjective character only in and as they correlate or engage underlying motor factors. The simplicity and directness of this engagement as implied by the model, and confirmed in experiments (some of which were mentioned earlier), lead us to expect that this more rapid rise of red should be accompanied by a more rapid engagement of the associated class of motor factors it induced. This may be taken as an explanation of the origin of the subjective character of red. The red excites flywheel representatives of classes of motor factors with a rapid manner of engagement that gives them a distinctive subjective character, often termed “aggressive" by artists.

On the other hand, the slow engagement of a motor factor gives more time for cumulation and inhibition effects to take hold. This accounts for the more passive nature of blue.

Children, when very young, prefer red, as it reinforces the class of motor patterns then most often emitted - those of thoughtless investigation. Later, as children need to integrate complex disciplines their preference shifts towards blue, as it reinforces the slower type of motor engagement of disciplined response. These represent examples of the broader principle that environmental factors are so arranged as to reinforce the abstract motor patterns or flywheel factors most needed in present model-building. Such arrangements contribute to a narrowing of random search.

That color differentiation depends on timing effects receives some added indirect support in the colorblindness that results from undercutting the link to temporal lobes where timing effects (as in hearing) are differentiated.

Now gestalts involving sudden rises are associated with relative cortical inhibition, and lower center dominance. The Russians have found that the threshold for red is lowered by what relaxes and lowers cortical excitation, as harmonious tones, etc., and is raised by what excites the cortex as random noise, which latter serves to lower the blue threshold. The argument would then go in this form. When the cortex is less excited, lower centers are less inhibited, and the patterns of motor activity will be more apt to be characterized by sudden rises and rapid change. The little child has a burst of activity just before sleep for this reason. Now red excites motor links which have this characteristic faster rise. Therefore, it should be easier to respond to red in this state of mind. When the cortex is more excited we have the same argument in reverse form applied to blue. It is significant that red is preferred by children in the early extroverted phase when the cortex is less active, and blue becomes progressively more important to them as they internalize discipline and the cortex becomes effective enough to subordinate rhythms which have origin in lower centers (as the "vegetive" or parasympathetic ones), a subordination manifest in the EEG.

Hence this color dependent effect and a variety of other related ones can perhaps be interpreted under the general principle that the motor patterns more characteristic of associated states of mind have lower thresholds when those states are present. The red gestalt, as thus interpreted, is the simpler gestalt, not needing or involving time for secondary responding or converging factors to distinguish it. It is therefore not surprising that red is the first color to be distinguished, and the first color to return after operations, etc. The next color to return is the other extremum, or blue, and after that colors come in by gradations between, orange, green, etc. This is a nice example of the principle that differentiation only goes by successive contradiction, that difference is enough to excite distinct motor sequence.

This theory of color lends itself to a simple test. If a sense of red is caused by a fast- off, and blue by a slow -off, one should be able to take white light and make it appear red or blue by turning it off faster or slower.

This prediction has been confirmed. It is known as the Benham's top effect. A top with a split black and white field may be greyed in and then spun in such a way that the white switches off slowly by stages to black in the outer part, and turns directly to black in the inner part. In this case, when rotated at a speed where the duration of the off-effects are comparable to that measured directly by Granit, the outer part of the top is tinted blue, the inner part red.

This explanation of the colors is a point of deepest philosophic significance. The subjective character of the colors has long been used in many philosophies as a classic example of the supposed absurdity of attempting to "explain" the subjective. How "explain" color, they say. This is a concrete model with which to answer them.

People once thought it most absurd to build models of matter too, for much the same reason. A careful examination of the symbolic relation of this explanation to the subjective it represents contains morals of deepest philosophic significance, which will be touched on in the last section.

### *13. Model-Building*

The controlling role of the model-building activity in the shaping of human emotions and personality is one of the implications of the present brain model.

We will very briefly try to suggest some of the leading features of its implications, without any attempt at justification, but merely for such suggestive orientation as it may afford. Books rather than pages are needed, of course.

An internal RD can be viewed as a prediction of human response. When we rationalize or verbalize our underlying feelings, the internal RD is often verbalized as the prediction of the emission of the response associated with the internally dominant loop. This internal RD engages such predictive word patterns. Our desires ''predict" our acts.

The internalized random search has the symbolic structure of a model for predicting our acts, and in order to do so it must become a foreshortened model of the world. The verbal function acts to help systematize, and remove inconsistencies as among the underlying motor RD. Because of the symbolic structure of these RD, such a verbal systematization constitutes a causal model of the world and our relation to it.

When we remember that models are at their roots, or as understood by us, models to help resolve subjective conflicts in the prediction or expectation of how we will behave, the centrality of the model-building process in the organization of the human personality can be better appreciated.

Increased causal insight has its subjective aspect as an increased ability to series elaborate our own acts mentally, But it is precisely and only series elaboration which regulates drives. This series elaboration allows us to isolate factors which narrow random search in a more radical degree. Compounded in the SS, an ability to predict further ahead leads to a greater selectivity or intercorrelation of human motor outputs, and the emergence of order out of chaos.

Now the relation of model-building to emotions can be briefly traced. The emotions are in a sense created to fill in gaps in our model-building. When we cannot internally predict out then the response level rises arid we enact. Emotions are closely related to alternations in the model, or inconsistencies in it. It is the alternation creates the emotion. In reverse, the building of an adequate model to resolve the alternation resolves the emotional issue as well. War is a part of education. One structures a situation by the control variables, and de facto the issues underlying war are resolved via the enlargement of or differentiation of the causal models of each.

Right motivation is not the problem. People overrun with motivations. The problem is to build models to help them predict out the drive factors they already have, not to implant new or added ones further complicating the picture. It is not inadequate motivation, but excess unneeded motivation, that is the problem, obscuring the self-sufficient self-regulating adequacy of our own internal model-building involvements.

The above scheme, so briefly presented, without supporting evidence, has a wide variety of applications, from the theory of history to psychoanalysis.

As an example of its application we might briefly outline, again without supporting evidence, and merely for its illustrative and suggestive value, the present model's critique of Freudian theories of the role of sexuality.

Freud discovered the intimate relation between the individual's adjustment and his form of sexual outlet. Roughly speaking, the form of sexual outlet serves to reinforce those abstract patterns of involvement in other bodies that are needed by one's model-building involvements of the moment. Thought, as Freud says, is sexual investigation. To stop thought, and to stop sexual investigation are one and the same act. Freud here uses the word sex in a very broad way, such that the parent's relation to its child is termed sexual. The intellect is based on the struggle to reconcile our motor patterns or the principles that synthesize them with those of others. The need to effect such a synthesis depends on sexual factors in their larger, more generalized sense. Thus, sexuality is closely related to model-building. It generates the most creative model-building needs.

Now Freud thought that one could resolve maladjustment by manipulating the sexual outlet. The best evidence is, however, against this. Maladjustments, like wars, are basically reflections of real intellectual problems not yet resolved in the culture. The need is not to avoid maladjustment, but to solve the cultural problems. The question is not why people break down, but why so few break down, in a culture loaded with lethal inconsistencies.

The emotional patterns cannot be manipulated directly, but only indirectly via the actual solution of the model-building issue or intellectual counterpart to the emotional issue. All emotional patterns are good in themselves, and if they lead to madness, as the fight for liberty leads to death, that is just part of the game. To avoid the dangers of madness implicit in attacking difficult problems is like avoiding the danger of death implicit in the fight for liberty. Such avoidance is only achieved at the price of arrested development, or slavery.

Another type of link between the present model and maladjustment lies in the recognition of the motor character of thought. Maladjustment should therefore have its motor aspects. The bringing into question of basic principles for predicting decision, caused by the interaction between modes of behavior emerging from different contexts, must have its aspect as disorganized motor coordination. Recent investigations have confirmed this inference. It is a test of the intimate relation between motor behavior and thought, as implicit in the model.

This recognition suggests the importance of clarifying the procedural motor roots of intellectual problems, if we are to resolve them. In relativity, for example, it was very important to go to an operational point of view to clarify the concept of simultaneity. In mathematics foundations the operational point of view, though inadequate to formulate answers, has never the less provoked many useful questions which prepared the way for a more complete answer using a model of brain function.

Such points indicate in a schematic way a few of the places of attack which this model-building view of the interior operation of the nervous system leads to in other fields. They are also examples of the link between the calculus and other fields, shown in Fig. II, which link, when traced directly in terms of wiring diagrams or behavior, remains obscure.

### *14. Character Type*

Personality can be classified in endless ways, and it is perhaps most important to realize how secondary all these ways are. All persons are "motor" types, all people are verbal types, all people are group oriented, all people seek inner consistency. Yet, if type distinctions are not exaggerated, they have a certain limited usefulness.

Roughly speaking, genetics only acts selectively with respect to available roles. People are far more plastic than we realize. Blocks lie at the model-building level, not the genetic level in present-day issues. All types lie in embryo in all people. A changed context converts introvert to extrovert, passive to active types, etc. In addition, the creative model-building issues of the present day require that we open in ourselves all these type aspects. As a result type is becoming less and less clearcut, as compared to the past. Modern man is not a type-man, but a drama-shop man, in which the voices of all types open and war. The truth is independent of type.

In future type labels may perhaps be more profitably applied to acts than individuals. We may say that this act or tendency reflects a passive introverted phase of a person's thinking or model-building while another act or another context exposes an extroverted phase, etc. People play different roles in different contexts, or with different people. Roughly, introverts build self-models, extroverts nature-models. But the same person may serve to represent aspects of self-models relative to A, social-models relative to B and nature-models relative to C, He may shift his whole interior rhythms from introvert to extrovert, depending on the relation of his models to the models of the person he is talking with. The class of facts or insights we are representing relative to the group sets our role, and this is a relative matter, which changes with both occasion and person.

Nevertheless, in children especially, and in the early stages of learning, type differentiation of individuals plays an important part. There are a wide variety of useful type differences, relevant to the prediction of different classes of response. One especially useful one is the introvert-extrovert distinction, which we will briefly consider in some detail.

Man is a social animal, and the character of his motor response is set by his response to people's demands.

Introverts over-respond to demands and so over-respond in motor terms. They go off in ways independent of their immediate nature environment. The over-response represents an overestimate of the power position of people. Romantic love, in the extreme form, has been called an introverted phenomenon. When examined from the point of view of schoolbook learning introverts are easily conditioned. The cortex functions inhibitively with respect to the lower centers, and the introvert has a more excited “normal" state than the extrovert, and so can be more easily inhibited, or conditioned to respond dependently to external demands. Pavlov called him the "cowardly" type. This over-response means a model-building more concerned with the integration or reconciliation of demands than the testing of them. As such it is oriented more by the muscular sense, and conceives the world as the body’s relation to itself in reconciling demands placed on it.

The extrovert under-responds in motor terms, and has a less excited cortex. In trying to roll a ball slowly along a line the introvert overcompensates sending it back and forth many times, but the extrovert responds more deliberately, and the ball crosses fewer times. He is less easy to condition in the narrow school-learning sense, because less easily frightened. However, when material is presented in a way adapted to his way of asking questions, extroverts learn just as fast as introverts as Pavlov and others have shown.

The extrovert tends to test demands, to test the present power structure, and so orients more in relation to his environment, or nature. He depends on the present environment for sources of motivation, and so responds more to colors and textures. One only sees things in and as he uses them in determining behavior. The over-responding introvert does not use his. relation to his environment to determining his act, and so does not see it as directly. The introvert sees in the environment only a secondary regulator of an independent internal intent, and so sees lines and corners more, in a flat and logically linked way. The extrovert feels the world more in three dimensional terms, as a set of interacting impulses, few of which are over-responded to enough in isolation so as to develop detailed line-like coordination of their implications. Middle types combine both extremes and are more socially oriented.

The extroverted models have more parallel content as internally viewed, they are open to more possibilities at once. The introverted model has more series content, or series elaboration of isolated points. Relatively constant sensory inputs send the extrovert to sleep, while the introvert thrives on it. Rapid changes throw the introvert into confusion, whereas the extrovert thrives on it.

In crisis we go to the opposite extreme to resolve. The introvert over-responds. The sympathetic side of the autonomic nervous system is more active. But in crisis the limit of this response is quickly reached, and he fails back on a parasympathetic response and sleep. Similarly, in the extrovert the parasympathetic side is more active. Hence, in crisis the sympathetic response dominates.

Such loose outline statements need a lot of detailed discussion, not only to justify them, but even to explain what they mean. Nevertheless, we can see in these considerations a variety of structural factors which directly reflect our underlying model of brain operation. The relation of motor over-response to type of model-building involvement is a very sensitive reflection of the simplicity of operation of the brain on the basis of internalized random search. Motor correlates have their direct translation into intellectual terms, since the intellectual models are compounded of them. A type of motor correlate implies a type of model-building interest that makes use of them. Over-response, for example, implies that one does not use a present dependence on the environment in defining that response. What is not actually used in the decision process is not perceived.

The translation into motor terms of physiological mechanisms (here, degree of excitation of the cortex) exposes the full subjective role of these mechanisms in thought since the internal loop processing parallels the external motor one. The organization of the nervous system about extremum responses helps confirm the emergence of type independence with increased differentiation. Since all types make use of all extremes, only in different orders or sequences, there is no deep genetic block separating type. This recognition is another example of the principle of internal plasticity implicit in the model, and the reliance on external structure for internal stabilization of such order as emerges.

In this section we have considered a random scatter of applications of the model outlined in Section I from neuro-physiology to theory of sensations, and psychoanalysis. The aim was merely to suggest the variety and scope of potential applications.

# III. The Status of the Word

In the previous sections we have roughly outlined an attack on a working causal model of the operation of the nervous system. In this section we will begin by assuming the complete success of that attack. We will assume that we will shortly understand the operation of the brain as fully and completely as we now understand the operation of a typewriter. Have we debunked man in building such a model? What does this mean for man?

To try to give a systematic answer to such questions in so short a space is clearly impossible. An examination of the status of these explanations or brain models, how they relate us to each other and the world, lies at the heart of the philosophic issues of our age. All we can hope to do is set forth an abstract unjustified scheme for the reader's consideration. If this scheme generates interest in longer studies now being rewritten, it will have served its purpose.

In the framework of the present model, what are we then to call ourselves? What are we?

The word is what most nearly corresponds to "ourselves" in many ways. Our bodies are as exterior and mysterious to us as anything else. Thought is discursive. It is embodied as ordered words. We know things not directly but via the word patterns they excite in us, This word has gradually grown in power, and in so doing has created a set of deep issues whose resolution involves the orientation of the place of the word in nature, and hence the place of man.

The problem of morals is the problem of building a model adequate to "predict out" or resolve the most pressing inconsistencies in the prediction of our acts, at the present drive level. Old models become inadequate as drive levels drop, because the lower drive level is more varied and harder to predict. Hungry terrified men can be organized by simple models, but not so a curious well-fed secure educated youth. Indeed, the power of the word is now such as to undercut all more primitive forms, so that it can no longer be regulated relative to underlying preverbal factors. The problem of morals was once to predict out hate, or physical warring interactions. Later as the commercial class displaced the warrior class the models had to be adequate to predict out greed, or commercial interactions. Now, however, the word so undercuts, that morals can ground only if deep enough roots are found to predict out curiosity, or the whole verbal function itself. How to do so, and what it means to try and do so, involves deep issues. It involves building a causal model of brain function, for nothing less can resolve conflicting predictions or orient the verbal function to that degree needed to coordinate the organized curiosity of scientific research.

We shall now briefly survey the symbolic structure of these issues, and then their resolution as they appear from scientific, personal, semantic, and religious points of view.

In so brief a time we can only aim at suggesting an overall pattern for an answer. We will open questions not close them, and even the opening will be left vague.

## 1. *The Drive for Consistency*

Deep is the power of the word to reshape our inner world. "Potato!" How that word grabs our inner being in the moment of its sounding, reshaping it as no tyrant ever could.

Because the word functions to systematize, or resolve inconsistencies among the internal RD that enter into the SS, the verbal order forms itself into a model of the world, paralleling the underlying order of the internalized random search. The word models by predicting ahead serve as a powerful catalyst, intensifying SS selectivity, and greatly simplifying conditioning.

So powerful is the word that the emotions may, in many respects, be viewed as created by ambiguities or inadequacies in verbal models. In so far as verbal insights are unable to predict the decision process, then emotions rise up to fill the gap. Only the process of differentiating models reduces the drive level. The word takes over from the passions. Instinct is subordinated by verbal models. Even love, one might say, especially love, now requires deep technical insights.

The involvement of words in the underlying life process pushes them gradually towards a deeper consistency. Methods of predicting our response in one area are forced into reconciliation with behaviors in others, because when they are not so reconciled the verbal response becomes unstable.

Consistency in a syntactic sense closely parallels the underlying SS condition. Words function to help systematize the underlying CR responses. (Here of course we use CR in its generalized sense including purely internal CR effects with no overt stimulus or response.) Thus the drive for a verbal consistency is linked to the 1st laws of operation of the nervous system. Its absence creates random searches and associated passions of great force.

Indeed, it is so powerful as to become self-destructive so that people need to develop protective devises against it. Operating on inadequate models, the push to consistency becomes the push to madness.

But this deep drive towards verbal consistency in each of us becomes a method of inter-control of one another, using only the laws of our own nature, and not depending on any special reinforcements, except the inherent self-reinforcement of the truth implicit in its consistency. This link between people, a purely syntactic link, will become an adequate source of control and shaping of behaviors to solve present problems once the verbal models in each are sufficiently differentiated. Indeed, this drive toward a verbal consistency may be regarded as the basic source of ordering that holds society together even now. It is verbal convictions, or causal insights, not force, that holds together. We cannot here begin to present the evidence for this point of view, we merely leave it as a suggestion.

This ruling others, only indirectly, via a verbal obedience, via a helping them to answer and make consistent their own internal verbalizations is at once the heart of certain interpretations of our Hebrew-Christian tradition, and the key to the power of the student centered teaching approach.

Now, as we have said, openness and consistency, or the forces that push us towards them, can appear subjectively as a fatal disease. Indeed, with the primitive models available in the past, the life process or our drive patterns, could only be sufficiently simplified so as to be predicted out by uprooting our sexual and worldly involvements. Yet so powerful was this drive, that even with primitive models it was able to push large groups of people towards inner consistency of a greatly limited premature type, in the shelter of the cloister. In so doing it helped propagate the verbal compulsions which underlie the creative scientific consistency of today which can use sexuality and make a heaven of this world.

Hypocrisy often seems the price of health, death the price of inner unity. Modern man lives in terror of his secret masochism, his secret tendency to probe and analyze himself in exacting detail which tendency paralyzes him and leaves him uncertain and helpless because he can find no answers. This probing self-consciousness, as it is pushed towards its ultimate implications, can seem to him nothing but an irrational morbid death-urge, leading nowhere.

Can this drive towards an open, selfconscious inner unity ever be indulged without sterility or madness? What is the origin of this schism we all feel in ourselves? What is the road through - if any?

### *2, The Schism*

What is the origin of this deep schism? One aspect of the origin is the short-range tactical disadvantage of openness and consistency when models are inadequate. It leaves one defenseless and paralyzed before any foe.

But there is a deeper side to this. The core of the matter lies rather in the presence of competitive moralities, or competitive models for the prediction of the decision process which have not been reconciled. On the one hand, there are a host of crude causal models derived from past concepts of the self - all inconsistent as among one another, but useable. On the other hand, there are the models of science, based on unqualified universals, but these have been, up to now, too weak and ambiguous to be useable in the prediction of wide classes of essential everyday life decisions, because the problem of the operation of the brain had not yet been solved in engineering terms. The absence of an adequate engineering model forced people back, in practice, on the variety of old, inconsistent, makeshift models of the past.

Now this situation is, subjectively, a nightmare. When there are two inconsistent models predicting the decision process, they produce alternation, and deep emotional involvement at that point. Either madness or hypocrisy is required when these alternations touch the more basic aspects of the organization of our decision processes. The link between alternation and emotional involvement points up the dangers of this situation.

But these very alternations force the invariant correlates to the surface by the 1st laws of operation of the brain. They force up the unqualified universals of science which alone can span the alternations. Science builds a model of the self, so that we may act in the perception of the cause, and use our engineering models to predict the act in everyday life.

This model constitutes the resolution of the schism at its heart. It bridges the gap, once thought impassable. This new emerging framework and associated new self-concept constitute the cultural revolution so long predicted by Spengler and Toynbee. But what does this resolution mean for us?

Science has now done what everyone feared it would. It has built a model of the seif, or parallel calculating machine, so we can understand it as easily and fully as we do a typewriter. People feared that this would debunk man, destroy important values often associated with our religious traditions, and indeed open a chaos of tyranny and power undreamed of. But paradoxically, what we most feared hid what we most hoped for.

We will now examine the larger aspects of this resolution from scientific, personal, semantic, and religious points of view.

### *3. The Resolution at the Science Level*

Let us first consider how this resolution takes place at the science level, and why it does not mean a debunking of man.

Science was once conceived as a limited problem. Its laws, once solved, might need further refining, but this refining was conceived as a sort of asymptotic approach to an established truth, with little social significance beyond a given point. This attitude is rapidly undergoing change. Every layer of differentiation of scientific models represents a revolution, not a mere refinement of the old. This revolution touches vast new sources of power. It allows us to predict our behaviors one stage further ahead than before. This in turn, when fed back into the SS condition, leads to an enhanced selectivity in or correlation of the emitted behaviors. Hence, the new scientific insights have their aspect as social transformations and psychological transformations as well. New scientific models have their aspect as new self-models, with associated new interests and emotions.

Now the result of this cascade of effects due to the solving of one level is to produce tools to dig down one level more. Thus the opening appears as transcendental.

This linkage of causal insight to morality and the institution, via the SS selectivity, allows us to orient life as the differentiation of our causal models as we once oriented it as piling up money, or conquering new lands. Man is a model builder. The control variables determining institutional change are in causal insights alone. Other factors lack the adequate invariance to take hold psychologically and wash themselves out in a situation with as many degrees of freedom as human society. We control others not by reinforcement, but by differentiation of their causal insights. Pavlov showed that differentiation was far more effective than any specific reinforcement or repetition in locking in or shaping response.

Now we can return to our original question. Why is a causal model of man not a debunking? The answer lies in the fact that the center of attention always lies in the inconsistencies, in the inadequacies of present models. We cannot predict what is emotionally significant to us as model builders and so debunk man, since that which is emotionally significant is precisely the inadequacies in our ability to predict.

Life is now oriented with respect to educational institutions and the processing of the differentiations of our causal insights rather than relative to the stock market.

The brain is indeed reduced to a kind of typewriter. As apart from its environment the body will soon be as debunked as is a typewriter apart from the author that uses it. Though the concepts via which we understand brain function involve stages of indirectly implied construction, or nature calculator stages, not present in our understanding of the typewriter, this indirectness does not make our basic understanding of its principles as an isolated machine less complete. But understanding does not debunk the body with an environment. We do not think that understanding a typewriter debunks the poem the poet writes on it. Neither does understanding the body calculator debunk the word patterns God or the environment induces in it. The class of correlates processed by our parallel calculator has origin from without, and is not implicit in its definition.

After discovering a new causal insight we can explain its causal emergence easily enough, using its existence as a pre-assumption - but only after!

if we substitute the word “environment" for "God" and "science" for "God’s laws" or "God’s will", etc. these conclusions closely parallel certain interpretations of the Catholic position on free will. Free will, Thomas Aquinas says, does not mean that man can act in opposition to God’s will (i.e. laws of science) - it only means that man’s understanding of God’s will (i.e. science) effects his acts. Evil is false knowledge (false causal insight). The struggle for union with God is, in modern engineering terms, the transcendental struggle to act in the perception of (i.e., with an understanding of) the cause, and resolve internal syntactic inconsistencies.

Aquinas' distinction between pantheism and Catholicism turns on a practical estimate of the power position of the word, and represents another point on which these answers could be interpreted as paralleling the Hebrew tradition on creation and the word which Aquinas expresses. He says in effect that pantheism underestimates the power of the word relative to nature. Pantheism sees the external order in nature as deeper than that of the word, so that the best man can do is adapt to it. The Hebrew position recognizes that the power inherent in the catalytic action of the word is enough to transform the whole face of nature, and this many times over, or transcendentally. The best present evidence tends to support this view though of course transcendental truths cannot be proven, only falsified,

*4. The Subjective Resolution*

Viewed from a subjective point of view a threat of debunking lies in the placing of the controlling or orienting aspects of the model beyond ourselves. If categories of the model determining institutional change do not correspond to factors in our immediate awareness and control, we are left in an awkward, twisted, indirect relation to the channels of power. But, as it happens, this global scientific model-building orientation has intimate and immediate subjective counterparts.

These counterparts are found in our understanding of the mathematical structure of the center of attention in objective model-building terms. Both subjective and scientific modes of orientation turn out to be at one, so there is no debunking.

Subjective expectation as to how we will behave has its aspect as a prediction, implicit in the very functioning of the nervous system. This constitutes a sort of functional definition of prediction. Our subjective understanding is ultimately linked to motor processes, even in the foundation of mathematics. We experience mathematical concepts as systematizations of the manipulation of symbols on paper.

Now the center of attention has two aspects, as a conflict in our subjective prediction of how we will behave, and as a syntactic contradiction which orients our scientific model building. The alternation associated with this conflict increases our involvement at that point till we can, in an enlarged model, find invariant spanning correlates that stop the alternation, and consistently predict the act in our internal model of the random search.

The verbal order functions to systematize the underlying CR order. Now it is only universals for which there are no exceptions that can be connected, as Aquinas says. Isolated or overstated correlates from different character types cannot be subsumed under common universals. But as a result of interaction, these isolated correlates are seen as part of an enlarged pattern. They are pushed to their implications, and via the study of their patterns of contradiction can then be connected.

All interaction which is subjectively significant has its aspect as verbal interaction, and contradiction of a syntactic type. War is a branch of education. It forces us to more invariant correlates, it forces us to resolve models for the prediction of the act. If war is outmoded in future, it will be because of the vastly more intense interaction that science makes possible.

Conflicts come to appear as due to inconsistent principles systematizing the underlying CR, and their resolution is via deeper causal insights that link these principles under common universals, and so make them consistent.

This purely causal approach to conflict does not destroy our traditional values, because of the model-building level at which the conflict is resolved.

A central example of this is the defense of liberty on causal grounds. Liberty is "justified" causally using only the relation of mobility to power, and so has a transcendental status independent of the level of causal insight.

This relation of mobility to power is beautifully illustrated by the game of chess. He who controls center squares has more mobility and, other things being equal, knows he will win (though he cannot tell how), for he has a deep confidence that in the turn of events mobility converts quickly to power.

These same principles apply to life, with even greater force. Added freedom or personal mobility is a weakness in life only when we have inadequate causal insight to use that added freedom or predict it out. As soon as causal insights are enough to span added freedoms, the interactions in the group force open this added freedom in each because by so doing they can beat those who don’t.

It is obedience which in the end best protects our inner freedom, our ability to follow our own impulses in the exact demanding artistic sense. It is not the freedom to move other people’s hands and arms as we like, but the freedom to move our own hands as we like that is craved, and that is found only through obedience. The conflicting demands of obedience force open our inner freedom, and give us means to protect it as nothing else can. And paradoxically only habits of obedience to others can give us the nervous energy to "obey" ourselves, or externalize our own inner ringing loops without distortion.

The regulation of others, only via the differentiation of their models, is thus set on deep grounds since this maximizes the freedom in each. It is only via building a causal model of the whole in each that one can maximize freedom in another and make him productively mobile as a model builder.

But to regulate another in this indirect way is to keep values in a causal status. In practice this means that values are only defined relative to drives. A value is only an answer to "how". The set of "hows", in combination, (via SS) indirectly imply a "what". A value is a statement of relative dominance as among equivalent or competitive techniques. It does not involve a violation of our spontaneous nature, or the use of words as sources of motivation, or hortatories. The truth or causal laws are enough. Thus the grounding of moral law on causal law, which at first seemed a threat, turns out to be a needed key to protecting our inner freedom. It was the second causality, a causality competitive with the scientific one and derived from earlier self-models, which gave rise to the "hortatories" that caused the inner confusion. The true law, as James says, is the law of freedom. The adequacy of. these unqualified universals to ground morals has been the guiding hope and prophesy of the constructive side of our religious traditions.

The seeking of inner verbal consistency has implicit in it the search for a causal model. The seeking to build a model of the whole is not a hortatory, but the very law of all men’s natures as Aquinas says. It is enough of a common fact to rule man by, and order society.

### 5. *The Semantic Level of Resolution*

What is the world "about?" Vainly one probes into it to find "basic" intuitions with which to justify, and on which to project or assign syntactic structure which is relevant to decisions. No such basic intuitions can any longer be isolated, adequate to form a foundation for modern issues.

In the Greek days one could. The underlying motor gestalts were then used as the basis of orientation, and no such terrible push to unqualified universals was contemplated. Lines and planes, as intuitions, could be abstracted from visual experience etc., and used to predict, that is justify, the word order. Similarly, "greeds" and "fears" could be abstracted from direct experience and used to predict the social order and so build a Roman peace.

But a radical transformation occurs in modern science. The word is no longer oriented by what it points to, as we understand the meaning of the word "wall" by "look"! Rather the specific sensation is oriented via the words it engages in the universal orienting calculus of physics, i.e. via the location of these words associated with the sensation in the syntax. In the Everett-Wheeler quantum theory formalism all treatment of subjective concepts once thought essential for orienting or anchoring physics, as for example the concept of a measurement, are replaced by a corresponding syntax in an enlarged model that includes in the syntax a model of the observer himself.

Consider the blueprint of a car. We already orient the meaning of the bolt more by its place in the blueprint, than the blueprint by its reference to sensuous bolts. In differentiating the causal models of physics this tendency reaches its absolute implications.

The final moral is that syntax can no longer be projected, and there is no need to do so. We understand a sensation via the verbal patterns it excites, and not directly via intuition. Our understanding is discursive, not intuitive.

This collapse of the ability to project structure is closely linked to the history of a search for a foundation to mathematics. The upshot of it is that after 50 years of search young mathematicians today don't bother to found mathematics, or give the syntax an interpretation. They call this the pragmatic attitude. There are deep reasons behind this. We can now live and coordinate without using a projection of syntax. The syntax itself provides, de facto, our basis of orientation in modern research.

The motive underlying the need for a "foundation" can be traced to the need to present a foreshortened causal model of the mathematical process, constituting its justification. But this justification we now effect by projecting the mathematical proof into an enlarged physics syntax using a brain model. This "founding" is trivial once one knows the answer, and it does not lead us beyond syntax. The unqualified universals that orient us in present engineering practice are not sensuous any more, but verbal. Things and sensation are treated as that which induces or links syntax.

People rule one another via the search for syntactic consistency which passion we share.

To summarize, a causal model of man once seemed a threat on the semantic level because it appeared to place the orienting structure, the things that determined institutional change, beyond our control or immediate awareness. Subjectivity might then seem to become an irrelevant epiphenomena. Paradoxically, however, this causal model of man turns out to return the cause to man. It leads to the discovery that the basic orienting structure and control lies in the syntax itself, and cannot be projected. The ultimate real is not only unknown, but unknowable. It can only be known in and as it links syntax, or is enacted by ourselves as word.

## 6. *Religious Level*

The power of the word implicit in these modern insights (which we have of course only superficially sketched) was guessed at long ago, and is implicit in Hebrew tradition. God is often called the word made flesh. The recognition of the central place of prayer is in its more constructive aspects the recognition of the central organizing place of the verbal compulsion acting freely for its own sake. The deep power of this insight lies in the mobility it opens. It unties people from the artificial constraints that projection of syntax gives rise to. Such constraints v/hen "believed in" impede creative readjustment. The closest one can come to truth is syntactic consistency.

Indeed, the new emerges from the chaos only via syntactic contradiction, as that which resolves it. The real is unknowable. The new is buried in statistics. When our models don't predict as they should we become emotionally involved in hate for the error and love for the truth which we feel in others but don't yet understand. The acting out of the passions has its syntactic side as an opening of contradiction.

Enactments of contradictions, or verbalizing them openly, pushes underlying invariants to the surface.

The "word" is a symbolic structure which functions as a powerful catalyst defining dominant SS, and so leading, via greater selectivity, to the emergence of order out of chaos. The unknown lies hidden in statistics. It emerges or is caught by indirectly inducing a correlation in our parallel calculator. In process of systematizing these correlations the unknown is forced to the surface.

Now the word lies at the very root of life. It takes over from symbolic counterparts in the chromosomes, and from preverbal symbolic aspects of our motor coordination and subjective awareness which served, on a more primitive level, a function which parallels that of the word.

This takeover of the word from underlying non-verbal symbolic factors has had associated with it extreme convulsions of a political and psychological type. The word had to incorporate in itself the causal principles implicit in the already existing order, or in the symbolic factors in chromosomes, and in the preverbal motor order already existing. To do so it had to probe them deeply. But at last we are reaching a stage where essentially the whole of the existing world order as thus far manifest, or emerged from the chaos, is subsumed by the present physics calculus.

This Stage might be thought of as that of the "union with God", the aim of our religious traditions. Creation will in future be organized not via the chromosome, but via the word, and self-consciously. The union ends the schism. It can be interpreted as the realization of the Jewish dream of life as the development of the ceremonial law, this law being identified now with that of science. The road to unqualified universals, especially emphasized in Christian tradition, via the "law of freedom" or the prediction of our own acts and the achievement of a personal unity at the sacrifice of group unity has paid off. What is most personal is also most universal.

The deep schism, the inner sense of contradiction, the secret masochism we all so fear, has opened so that it need be feared no longer. The cross or death that was once the price of inner unity has been made to open as the scientific processing of contradictions. The cross opens into joy, for via the research institutes these deep private conflicts can be faced into and successfully processed. Hypocrisy is no longer the price of sanity. Obedience forces open rather than suppresses the spontaneous freedom in each, when pushed to its furthest implications. The triumph of the word which seemed at first death turns out to hide within the death itself, within the principle of internal contradiction, a transcendental opening that promises soon to destroy death in the material sense, as too inefficient a technique of preserving plasticity and mobility. If the old orienting bonds of instinctive imitation and worldly love or dependency prove inadequate and collapse, in their collapse each gains alone the wholeness and energy he could never achieve in a group. As God divided we meet at last, and the death-like pain, implicit in the aloneness of modern man, is made to dance.

### 7. *A Summary*

We have outlined how the methods of indirectly implied construction, so effective in physics, can be extended to the operation of the nervous system. Instead of verifying the facts, we verify the principles of construction or the underlying universals in very special cases, and then use nature as calculator. In so far as this method is successful, it unifies the interpretation of our inner world. It treats life as a transcendental problem in mathematics, in which sensations can be represented via the syntax it interlinks. Sensations are treated as mathematical concepts to be identified. The schism caused by our inability to resolve under common universals the principles used in predicting our behavior, ends. Every aspect of the body’s response, as every effect in chemistry, can be treated as a "nature calculator" result. In this way thought achieves an intimacy of union with matter and subjective awareness which only the mystics guessed was possible.

This union, in its early stages, appeared as a threat, a debunking of man. However, a more careful examination shows it to be quite the opposite, a returning of man, as word, to the very center of creation. God, as Thomas said, cannot even reflect on himself except via man. Man is essential to God’s perfection.

On the scientific level this action in the perception of the cause, this achieving of an adequate causal model of man, is not a debunking, because the causal laws appear to be transcendentally differentiable, and each layer of such differentiation involves social and psychological and metabolic revolutions.

On the personal level the union is not a debunking, because the spontaneous center of attention lies precisely at those points in causal models which are inconsistent, at the points of alternation in prediction of the act.

On the semantic level the resolution is not a debunking, because syntax structure cannot be projected. It is the syntax itself, our own enactment as word, which serves as the only basis of orientation of man as model builder.

And on the religious level, we find that this causal model of brain operation leads, paradoxically not to an overthrow of what is subjectively significant and valuable in our traditional religious models, but rather to a rediscovery. Hidden beneath a deep layer of paralyzing ambiguity religious models hold many deep insights whose constructive aspects can be reformulated in model building or engineering terms.

We began by discussing the relation between the world of measurement or physics, and the world of order. In a sense the world of order is understood via the world of measurement, the calculus of physics orients the concepts used to predict brain operation, as it does the special working concepts of chemistry.

But as we examine the basic concepts of physics, such as the notion of measurement as a comparison of internals, we find ourselves returned once more to concepts of order for their orientation. A new physics could well base itself on something other than the comparison of intervals. Already, counting processes seem more basic in many contexts (though of course one can artificially force anything into any mold by elaboration and treat counting indirectly via comparison of intervals ).

Thus the world of order comes to appear more basic than the world of physics. Length, or comparison of intervals, is understood as a very special type of order whose orienting prominence is linked to the present stage of differentiation of our causal insights, and so has no absolute or transcendental status.

The transcendental insights associated with religious tradition are not understood directly, but only via their reflection in matter, or the present level of causal insight. Nevertheless, they are not tied to this order, but are reflected in regularities of a type most simply formulated when formulated in a way independent of the specific causal insights of the present age.

The world of order is deeper than the world of physics. Syntax cannot be projected. The discovery of this plasticity of the world before the word, returns man to the center of creation.