

**ELEMENTARY SELF-REPLICATING INSTRUCTIONS
AND THEIR WORKS: TOWARD A RADICAL
RECONSTRUCTION OF GENERAL ANTHROPOLOGY
THROUGH A GENERAL THEORY OF NATURAL SELECTION**

Communication to the Ninth International Congress
of Anthropological and Ethnological Sciences

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A reconstruction of Darwinism, the proposed theory has two integrative effects upon anthropological and ethnological science: it brings genetic and cultural evolution into a common conceptual framework, including a common system of notation, and it reconciles hitherto opposed viewpoints in cultural anthropology -- the evolutionisms, the functionalisms, and the historicalisms. For example, the evolution of functional social "structures", as well as of functional material structures, is rendered explicable.

Materialistic, naturalistic, mechanistic, deterministic, the theory purports to account for all known biological, social, and cultural phenomena and to contain no terms or concepts not reducible, in principle, to physico-chemical terms.

Interpretation of the theory into empirical observation-statements is touched upon but not vigorously pursued in the present communication. Its powerful ethical and political implications also receive only brief mention.

Key terms developed in the communication include: 'determinant', 'behavioral event', 'event of natural selection' ('ENS'), 'replication', 'self-replication', 'elementary self-replicating instruction' ('SRI'), 'cooperation', 'competition', 'exploitation', 'domestication', 'system (of instructions)', 'function (in a system)', 'environmental sub-region', 'frontier (between sub-regions)', 'evolutionary event', 'organism'.

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PREFACE

This communication is to introduce the fundamental concepts and relationships of a theory on which I have been working for the last several years. The theory, in turn, will attempt to furnish a framework for the study of evolutionary *events* in the realms of both genetics and culture, in order to account for many hitherto unrelated generalizations and to reconcile opposing theoretical viewpoints.

My choice of the word "events" is most significant here; in my view, evolutionary studies in both biology and cultural anthropology have erred heretofore by concentrating on the *results* of evolutionary events (usually on the results of many recurrences of like events), without getting down to the essential nature of the evolutionary events themselves.

Concern with results rather than events has led us, for example, into the trap of having to define "success" or "fitness". Seeking to avoid defining "success" in evaluative terms, we try to quantify it: A more successful form has more representatives than a less successful form. So Starfish -- or Antelope -- is more successful than Lion? But Lion's "success" (in evaluative terms -- sorry) is clearly dependent, in part, on self-limitation of Lion's numbers!

So we try again. We redefine evolution in terms of changes in gene frequencies in a single population, caused by natural selection -- which we now redefine as *its* result, "differential reproduction" (formerly "survival of the fittest"). But now we have lost the essential meaning of evolution; we have reduced it to a relative thing (implied by the use of *frequencies*), to one of its minor aspects; namely, competition of allelic genes for a particular locus on a chromosome. If we apply this conception of evolution with any rigor, there can have been no evolution before the (evolution of the) chromosome; there can be no additive evolution (and hence, little or no evolution of species) and there can be no cultural evolution, since cultural elements, whatever they may be, are certainly not tied to any analogue of the chromosome. (Any human brain can carry far more cultural instructions than any human brain does in fact carry.)

Furthermore, the relationship between evolution and adaptation to the environment has become attenuated to the point where evolution and ecology are almost separate sub-disciplines.

PART I. THE MICRO-EVENT CONCEPT OF EVOLUTION

The conception to be introduced in this communication can be quickly summarized as follows. Elementary self-replicating instructions are the constructors of life and, given life, of culture (in the sense that coral polyps are the constructors of a reef). These elements are material structures which can do behavioral events, some of which happen to be events of natural selection. Through events of cooperation (a form of natural selection), the elements form systems of elementary instructions (sometimes including secondary structures and instructions), each of which has a function in the system. Modified spontaneously from time to time, generally by addition of novel instructions, a system may propagate, step by step, into ever more hostile microenvironments (biotopes, spatiotemporal *sub-regions*). Competition is a special case of the latter process, where the presence of the evolving system itself makes the occupied sub-region become ever more hostile.

Utility.

This micro-event-concept of evolution can be used to account for a number of macro-evolutionary generalizations. For example, an evolutionary stage or grade is an empirical generalization based upon observations of the results of roughly similar *trends* in different family lines (of genetic or of cultural systems); a trend, in turn, is a sequence of roughly similar changes (usually additive) in a system's instructional repertory, as it propagates into sub-regions ever more hostile along a gradient of some sort (perhaps a system-self-induced gradient); each change in instructional repertory, finally, results from an immense number of events of cooperative natural selection, through which a novel instruction propagates within each sub-region.

Instructions. Events. Behavioral Events.

An instruction, in general, is a *material structure* which, in certain environments, has the capability of behavior -- of responding to a certain cue in a certain way.

Any particular kind of material structure, whether an instruction or not, can be defined in terms of the necessary *material conditions* for its occurrence in any spatiotemporal location.

These material conditions can be divided into three classes -- (1) the "background" conditions, (2) the "immediate" conditions, and (3) the "uniquely defining" condition. Very roughly, these

three classes correspond to (1) the ranges of values of environmental variables under which the parts of the material structure can be present, (2) the actual presence of the parts, and (3) the sequencing or relating and connecting of the parts. (It should be noted here that a condition in any of the classes can be stated in terms of ranges of values of variables, albeit complex variables, some of them perhaps dichotomous variables.) As a rule, conditions (1) are necessary for conditions (2); conditions (2) are necessary for conditions (3); and conditions (1), (2), and (3) are severally necessary, and collectively sufficient, for the occurrence of a structure of the given kind at a given location. If the material structure in question is an instruction, I refer to these material conditions as the *S-conditions* of the instruction -- meaning its *structural* or *storage* conditions. Thus if, and only if, all the S-conditions of an instruction of kind *i* are met at location *l*, then *i* occurs at *l*.

The meeting of an S-condition, followed by the occurrence of an instruction at a particular location, is an example of what I mean by an *event*. We can illustrate such an event diagrammatically, thus: $X \rightarrow i$. $X \rightarrow i$ reflects the fact that the value of variable *X* at, say, location *l* is a *determinant* of the occurrence of instruction *i* at *l'* (perhaps $l' = l$). More precisely, $X \rightarrow i$ means (a) that *i* occurs at *l'* and (b) that *i* would not have occurred at *l'* had the value of *X* not fallen within a certain range of values at *l*.¹ More briefly, we can say that an S-condition (*X*) of *i* has been met at *l* and *i* accordingly occurs at *l'*.

The exact same causal relationship obtains between any material structure and any one of its material conditions, of course, and can be diagrammed accordingly: $X \rightarrow S$.

An instruction, however, differs from an ordinary material structure in that inherent in its structure is the capability of behavior *i* mentioned before. Once it occurs in a certain location, under certain additional environmental conditions (values of certain variables falling within certain ranges), which I call *Q-conditions*, an instruction-structure *changes* the value of some environmental variable, generally by converting energy. I call such an occurrence a behavioral event, and illustrate it diagrammatically thus: $i \rightarrow X$. $i \rightarrow X$ means that a behavior of instruction *i*, at some location *l*, is a determinant of some value of variable *X* at some (other) location *l'*. More precisely, $i \rightarrow X$ means that the value of *X* falls within (or outside of) a certain *range* of values at *l'*, and that the value of *X* would have fallen outside of (or within) that range had *i* not behaved at *l*.²

Events of Natural Selection (ENS).

The class of behavioral events includes a relatively small subclass of events which I call *events of natural selection* (ENS). In an ENS, the behavior of an instruction i at l meets or maintains one of its S-conditions -- which would not otherwise be met -- at some other spatio-temporal location l' , and thereby i occurs at l' -- where it would otherwise not occur. This kind of event can be illustrated diagrammatically thus: $i \xrightarrow{X} i$, $i \xrightarrow{X} i$ means (a) that i occurs at l' , (b) that i would not have occurred at l' had the value of X not been within a certain range of values at l' (perhaps $l'=l$), (c) that the value of X was within that certain range at l' , and (d) that it would have been outside that range had i not behaved at l . It seems clear that the "arrow" relation is a *transitive* relation; i.e., that the behavior of i at l is a determinant (in the above sense) of the occurrence of i at l' .

If l and l' differ in space (as well as in time) the ENS (event of natural selection) results in replication of i (but not necessarily in *self*-replication -- see below).

If l and l' differ in time only, the ENS results in *endurance* of i .

In certain environments, then, some instructions determine their own reoccurrence by means of their behavior; i.e., they "ENS." In especially favorable environments, an instruction may ENS repeatedly,³ with the following cumulative results:

Repeated replications of i result in propagation of i in space.

Repeated endurances of i result in survival of i in time.

Propagation and survival of i are, generally, essential to each other and also to i 's having "evolutionary significance"; i.e., to l 's coming to the attention of students of evolution.

The "especially favorable environment" in which an instruction survives and propagates is, of course, *bounded*; we shall refer to it below as a *sub-region*. Beyond the boundaries, or frontiers, of that sub-region are sub-regions where it cannot ENS, cannot replicate and/or endure, thus cannot propagate and/or survive.

'Function': A Preliminary Consideration and Partial Definition.

Consider, if you will, the possibility that i engages in two kinds of behavioral events, $i \xrightarrow{X}$ and $i \xrightarrow{Y}$, but that only $i \xrightarrow{X} i$. If the latter ENS occurs repeatedly, and i thereby propagates and survives in a certain sub-region, we can say that the behavior that brought variable X into the S-condition defining range is "*functional*" for i or, for short, " i 's 'function' is to X "; but the same cannot be said for Y .

In other words, we are defining the function of an instruction i as that behavioral result through which i repeatedly ENSes. Following that definition, we note that the occurrence of i at many locations in a sub-region is determined by l 's performing its function.

But we note, also, that this usage of 'function' is unparsimonious, since it merely restates the fact that the occurrence of i is determined by l 's "X-ing"; i.e., by the fact that i repeatedly ENSes by bringing variable X into range. We shall add conceptual content to 'function' shortly, when we discuss the concept of 'system'.

While ENS are essential for evolution, they are not *per se* evolutionary events, since they do not involve change in form or structure through time; evolutionary events are, rather, a subclass of ENS, as we shall show later on.

Events of Self-Replication. Elementary Self-Replicating Instructions (SRI).

Let us now look again at our basic diagram for ENS: $i \xrightarrow{X} i$. The X in our diagram can refer to a variable defining an S-condition of any of the three classes of S-conditions stated above: a background S-condition, an immediate S-condition, or the uniquely defining S-condition of i . We recall that the latter -- the uniquely defining S-condition -- generally refers to the arrangement or sequencing or connecting of the parts of the instruction/structure. An ENS (event of natural selection) in which i meets its own uniquely defining S-condition is an *event of self-replication*. For such events, we adopt a special form of the arrow-notation, thus: $i \xrightarrow{U} i$; $i \xrightarrow{U} i$ means simply that i occurs at l' , and that i would not have occurred at l' had the behavior of i at l not met the uniquely defining S-condition of i at l .

On page 2 of this communication we stated that "Elementary self-replicating instructions are the 'constructors' of life and, given life, of culture." We are now ready to define "elementary self-replicating instructions," which we shall hereafter refer to as "SRI": An SRI is an instruction which (1) engages in events of self-replication, (2) engages in behavioral events of at least one other sort, and (3) is not composed of parts which are SRIs; i.e., which meet criteria (1) and (2). Criterion (3) is, of course, what makes an SRI "elementary".

Because of their dual nature, SRIs have evolutionary potential that singular primitive instructions lack. So, although there is every reason to suppose that SRIs originally evolved from singular primitive instructions, all subsequent evolutionary history has involved SRIs as the essential units, and we shall concentrate our attention upon them and their products, including singular constructed instructions, from now on.

There are two principal kinds of SRIs -- genetic and cultural. Genetic SRIs are, of course, made of DNA, and take the form of genes -- although a strong argument could be made for considering codons, or even individual nucleotide units, to be the genetic SRIs. Cultural SRIs, on the other hand, include among their S-conditions the products of thousands of millenia of genetic and, more recently, neurogenetic evolution. Their components are neurons chemically linked in specific ways. They are carried only in human central nervous systems (although their precursors are found in the nervous systems of other primates). They are self-replicating only because of the capacity of human nervous systems for very exact *copying* -- of both Q-conditions and behavior; i.e., because of a highly refined form of observational learning. Each cultural SRI consists of a complex neural pathway linking one complex sensory input pattern (Q-condition) with one complex motor pattern (behavior), subject to other Q-conditions: various and sundry motivation-state input pathways -- drives, moods, memories, etc. Acquisition time and execution time are on the order of 1/10 second. Like genetic SRIs and genetically constructed instructions (enzymes, hormones, neurons, muscles, glands, reflexes, etc.), they are generally executed in fixed sequences, the behavioral results of one serving as a Q-condition of the next.

While there are important differences between genetic SRIs and cultural SRIs in their specific mechanisms of self-replication, storage, cueing, and behavior, and while the specific results of their behaviors are often different (e.g., genetic SRIs construct organisms and cultural SRIs do not), we maintain that the fundamental evolutionary processes are the same for both. Unless otherwise indicated, therefore, the following discussion of those processes applies to both cultural and genetic SRIs.

The Evolutionary Equivalence of Homologous Instructions (i=i).

When two SRIs occur under the same uniquely defining S-conditions, they are homologues or, in another manner of speaking, they are two occurrences or instantiations of the same SRI; generally, but not necessarily, they are self-replicas one of the other or of a common SRI-occurrence in still a third location. In all evolutionary processes, homologous SRIs are absolutely equivalent. For example, consider the following ENS, where i is an SRI (from now on, lower-case letters will always designate SRIs): $i \xrightarrow{X} i$. Here, i-at-l meets an S-condition X of

i at l' and i-at-l self-replicates into (meets the uniquely defining S-condition of i at l'). So i ENSes. Consider, again: $i \xrightarrow{X} i$. Here, i-at-l meets an S-condition X of i at l' and i at some

other location self-replicates into l'. Again, i ENSes. These two events are *precisely equivalent* from the point of view of evolution. It makes no difference which *instantiation* of i does what. So, since we have already specified that j is an SRI, we can simplify either diagram into $i \xrightarrow{X} i$.

Anyhow, since all our elemental instructions are self-replicating, we cannot use self-replication to explain their evolutionary distribution in space/time. We must focus our attention, instead, on the non-self-replicative behavioral events characteristic of different SRIs.

Other Simple Events With Behavioral Events as Determinants.

The symbol \sim over an SRI (or any other structure or instruction) indicates that the SRI does *not* occur in some location l'. Thus, $X \xrightarrow{\sim} i$ means that i does not occur at l', and that i would have occurred at l' had the value of X not been outside of (or within) a certain range of values at l'. So $i \xrightarrow{X} \sim j$ indicates a "lethal" behavioral event, a sort of "anti-ENS", and $i \xrightarrow{X} \sim j$ indicates that i's behavior at l' *prevents* j from occurring at some location l'.

$i \xrightarrow{X} j$, on the other hand, means of course that i's behavior at l' is a determinant of j's occurrence at l'; in a very simple sense of the term, j *exploits* i.

A Q between arrows connecting two SRIs or other instructions indicates that a behavior of the first instruction at l' meets some Q-condition -- which would not otherwise be met -- of the other instruction at l'. Thus, $i \xrightarrow{Q} j \xrightarrow{X} i$ means that i, at l, cues j at l' and that the behavior of j at l' determines that the value of X falls into a certain range at l'.

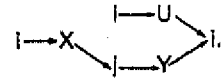
$i \xrightarrow{Q} j \xrightarrow{X} i$ is accordingly an ENS for i and an event of exploitation (i exploiting j) as well.

Reciprocal Exploitation.

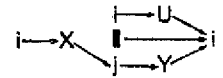
It is possible, of course, that events of the following sorts may both occur in a sub-region: $i \xrightarrow{X} j; j \xrightarrow{Y} i$. If these events are quite unrelated and occur only rarely, they are simply cases of reciprocal exploitation. If the events occur frequently and more-or-less alternately, however, they result in propagation/survival of both i and j in the sub-region, as: $i \xrightarrow{X} j \xrightarrow{Y} i \xrightarrow{X} j$, etc. This means that the behavior of j at l' is a determinant of i at l', but j wouldn't have *been* at l' if i hadn't behaved at l'. Thus i ENSes (and j also, by the same means).

Furthermore, recalling that i and j are SRIs (elementary self-replicating instructions), we see that i must have determined not only that j occur at some l', but that j occur at an l' bearing a

certain spatio-temporal relationship to a location where i occurs, so that when j meets S-condition Y of i at l', i can then self-replicate into l'' from that location, thus:



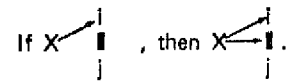
We indicate the spatio-temporal relationship that must pertain between i and j if i is to be replicated (to ENS) with a heavy bar; since the bar-relationship is thus a determinant of i-at-l'', we may indicate that determinism by the usual arrow:



Determinants of Spatio-temporal Relationships Between Instructions: 1. "Weak" Determinants.

If i and j are to occur in a certain spatio-temporal relationship R (=bar), they must occur in locations -- say l and l', respectively -- that are in R. Thus, the occurrences of i at l and of j at l' are among the determinants of their being in R. Since the determinant-relation is a transitive relation, any determinant of i's occurrence at l or of j's occurrence at l' is thus a "weak" determinant of i and j being in R. We call it a "weak" determinant because of its essentially tautological (analytical) character, because it could be materially trivial, and in order to contrast it with the direct material determinants ("strong" determinants) to be discussed below.

If we were to show the weak determinant-relation by the usual arrow, we could write a general rule as follows:

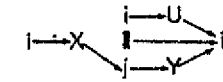


Since this is a general rule, however, the arrow representing the weak determinism adds nothing to the conceptual or empirical content of the diagram, so we will not use it in the future.

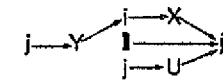
Cooperation.

Weak determinism or strong, however, repeated events of reciprocal exploitation in a sub-region amount to events of co-operation, which we shall now illustrate and define.

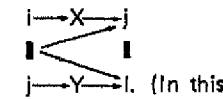
In the following diagram, identical to the one shown above, we note that i is a weak determinant of bar, and bar is a determinant of i: i ENSes; j exploits, and is exploited by, i.



Here is the reciprocal of that diagram



If the events represented by those diagrams are repeated, paired reciprocal events can be illustrated as follows, as events of cooperation:



The bar in this diagram represents a complex relationship, a logical product of the relationships represented by the bars in the preceding two diagrams.

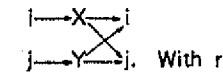
The important point to note in this diagram is that the bar relationship between the behaving i and j at the left is a (weak) determinant of the bar relationship between the i and j occurrences on the right.

An event of cooperation between i and j, then, is defined as follows: (1) i and j occur in locations bearing a certain spatio-temporal relationship to each other and (2) they would not occur in those locations had not i and j behaved in other locations bearing that same spatiotemporal relationship to each other.

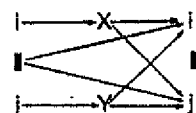
An event of cooperation thus includes replication not only of each cooperating instruction, but also of the relationship between them; in fact, each instruction ENSes, and the relationship ENSes as well.

In the diagram representing cooperation above, each SRI (i,j) meets a different S-condition of the other (i → X → j, j → Y → i), and (not shown, according to our convention) its own uniquely defining S-condition (self-replication).

More commonly, however, since i and j share many immediate and indirect S-conditions, each meets an S-condition of itself as well as the other, as

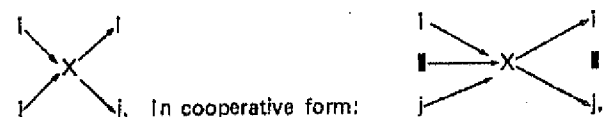


With repetition of these events of combined ENS and reciprocal exploitation, events of cooperation more constraining than the ones shown previously emerge:



This relationship is more constraining than the other because not only must i's "X-ing" and j's self-replication be spatiotemporally related in a certain way, but j's "Y-ing" must also be spatiotemporally related to those behavioral events in a certain way, if j is to re-occur; and similarly for re-occurrences of i. The bar, then, indicates that all these necessary relationships hold.

Another likely possibility is that i and j both operate on the same variable, together meeting an S-condition of both, as



Here i and j must interact while in a certain relationship in order to meet S-condition X of i and j; hence the arrow from bar to X instead of arrows directly from bar to i and j.

Still another possibility is that one SRI cues the other, which then meets an S-condition of both, as:



In all these examples, of course, the bar relationship determines the re-occurrence of the SRIs and, indirectly, weakly, of itself.

Conditions of Cooperation. Sub-region. Frontiers.

There are two categories of necessary conditions if two or more instructions are to cooperate: First, their behaviors in relationship R at certain locations must be sufficient to bring about their occurrence, in relationship R, at certain other locations. Second, the behavior of each in relationship R at certain locations must be necessary for their occurrence in relationship R and, indeed, for the occurrences of any of them at all, in certain other locations. These categories of conditions follow from our definition of the determinant (arrow) relation. (The first condition follows from the part of the definition which states that, in fact, the structures occur or the values of variables fall within (outside of) a certain range. The second condition follows from the part of the definition which states that the structures would not have occurred, etc., if the instructions had not behaved, etc.)

So cooperation between i and j takes place, if it takes place at all, only under certain environmental conditions. It takes place only in a sub-region, or biotope, (1) where the initial values of X and Y are not in the S-condition defining range for i or j or both; (2) where the initial values of all environmental variables except X and Y are in the S-condition defining range for i and j; (3) where all Q-conditions of i and j are met (initially or by behavior of i or j); (4) where the behaviors of i and j bring (or keep) X and Y, respectively, into the S-condition defining range for i or j (or both) at certain locations; and (5) where these events occur, and reoccur, in the necessary spatiotemporal relationships (either by chance or by behavior of i or j). The sub-region where events of cooperation take place among a given set of instructions is thus very strictly defined.

A sub-region is a four-dimensional area of space-time within which a given set of instructions cooperate to survive/propagate if they all once occur there. It is bounded by various frontiers. Across one or a very few of these frontiers the instructions cannot cooperate because environmental conditions (1) are not met -- the environment across that frontier is "too easy" for the instructions, they can propagate/survive without cooperating. Across the other frontiers condition (2), (3), (4), or (5) is not met in one or more different ways -- the environment across those frontiers is "too hostile" for the set of instructions, so none of them can propagate or survive even if they all occur there.

(From here on, we will frequently ignore the "too easy" frontier; evolution, as we shall see, takes place across frontiers into hostile sub-regions, and competition generally turns "easy" sub-regions into hostile sub-regions, in time.)

System.

When a set of instructions propagates and/or survives in a sub-region through cooperation (i.e. the set survives/propagates, and does so only if the components cooperate), the set is a system of instructions. The system, in a word, emerges from the repeated cooperative interactions of the individual instructions with the environmental variables in the sub-region.

Each instruction has a function in the system; i.e. a behavior/behavioral result through which it meets and/or maintains an S-condition of one or more other instructions. If any component instruction fails to perform its function, the entire system fails to survive or fails to propagate; i.e., no instruction survives/propagates.

Consider a very "loose" situation, where there are no material bonds linking one instruction with another; the instructions float about in a fluid medium of some sort.

(1) In a "too easy" sub-region, where they don't have to cooperate, the various instructions will be either scattered at random or, if they appear in clusters, these will tend to be clusters of like instructions (homologues).

(2) In the sub-region where they cooperate, they will tend to appear in clusters representing complete sets (assuming that one of the characteristics of the bar relationship is spatiotemporal proximity); for, if one instruction floats away from a cluster the entire cluster will deteriorate. If the lost instruction was maintaining an S-condition of other instructions they will be eliminated at once, and thus no longer maintain the S-conditions they maintain, etc. If the lost instruction was meeting an S-condition of other instructions, the others in the cluster will be unable to propagate and will eventually decay without issue, to be replaced by a complete set (system) propagating from somewhere else in the sub-region.

(3) In a hostile sub-region, none of the instructions will appear at all.

Thus, even without material bonds, with only functional "bonds", a system of instructions is a real material entity which occurs or fails to occur, depending on environmental conditions, on an "all-or-nothing" basis.

Function (II).

We are now able to use the term "function of i" in a way that does more than merely restate the concept "ENS of i". To do so, we restrict its use to the context of a system; i.e., we must now refer to "the function of i in system i = j."

The function of i is what i does for the system. At the same time, of course, the system -- the cooperative interaction of the whole set of instructions with the sub-regional environment -- maintains S-conditions of i. Thus the function of i is still the means by which i ENSes; i.e. by which its behavior at i determines its occurrence at i'.

We are now led to a rather striking conclusion: i's material presence in a certain spatiotemporal relationship with other instructions is determined by its performing a function in a system. That function, in turn, is determined in part by the S-conditions (or Q-conditions) of other components of the system, which it meets or maintains. Suppose, for instance, that the only function of i in a system is to alter the value of X to meet a certain S-condition of j. Suppose that a novel instruction j' (a mutant) appears, which performs the function of j, but for

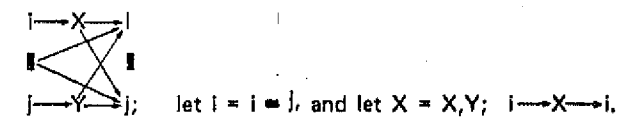
which the initial value of X in the sub-region is in the S-condition defining range. Wherever j' appears in the sub-region, then, i has no function; in those locations, i is a passive parasite exploiting the system. Formerly, whenever and wherever i decayed or was accidentally destroyed or floated away, none of the instructions could survive/propagate, so wherever instructions appeared, there, as a rule, would be i. Now, wherever j' has propagated to, the other instructions can survive/propagate without i. In time, i occurs less and less frequently because it has lost its function in the system. (Note that this does not mean it has lost its behavior, but only that the behavior is no longer functional for the system.) Thus, in a very real material sense, a system of instructions functionally determines its components.

Environmental Determinism.

We said above (p. 11) that "The sub-region where events of cooperation take place among a given set of instructions is thus very strictly defined." A system being dependent upon a given kind of event of cooperation, it follows that the environment of a sub-region exerts a very precise control over what systems can occur in that sub-region. For instance, in the example just used above, suppose that instead of a mutant instruction j' appearing, the initial value of X in the sub-region happened to change, moving into the S-condition defining range for j. i would lose its function just as before, and would be materially eliminated, in time, just as before.

Simplification.

We noted above that a system, like an SRI, propagates/survives on an all-or-none basis in any given sub-region. If it is to propagate/survive, furthermore, all its components must behave and, hence, the Q-conditions of all its components must be met. In short, the evolutionary significance of a system depends on precisely the same -- though perhaps infinitely more complicated -- factors as does the evolutionary significance of an SRI. (Indeed, from the point of view of an SRI, the rest of the system is part of the sub-region; i.e., part of the SRI's environment.) Thus, we can simplify a diagram representing a system, letting 'I' (or whatever) stand for the whole system and 'X' (or whatever) stand for any number of variables. We can show this simplification as follows:

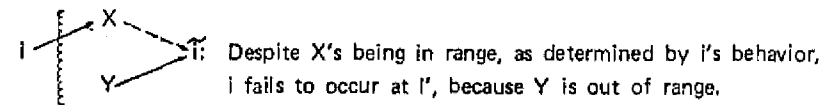


Then if we wish to, we can reintroduce 'j' as a new SRI, and Y as a new variable, in diagramming subsequent events.

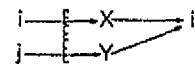
Mutation. ENS Across a Frontier.

Let us now consider a large region. The values of any given variable are not distributed through this region at random, in most cases; rather, they exhibit *gradients*, or *clines* -- we are thinking of such variables as temperature, acidity, and concentrations of particles of various substances and of material structures of other kinds.

Somewhere in the region, a certain SRI or system, *i*, propagates and survives, up to the boundaries or *frontiers* of its sub-region, through repeated ENS: $i \rightarrow X \rightarrow i$. (The wiggly line represents a frontier.) Beyond that frontier, *i* is unable to ENS because the value of some variable *Y* is outside the range defining an S-condition of *i*. We assume that *i*, at some location *l* in the cis-frontier sub-region, is behaving and having its usual effect at some location *l'* in the trans-frontier sub-region, $i \rightarrow X$, but cannot ENS across the frontier solely because of the value of *Y*. In the hostile trans-frontier sub-region, then, $Y \rightarrow \bar{i}$.⁴ To illustrate the entire event in one diagram, we have to introduce a new symbol, the broken arrow \dashrightarrow , which means "despite." (The logic of this symbol is analogous to, though more complicated than, the logic of the unbroken arrow symbol.) The frontier event appears diagrammatically as

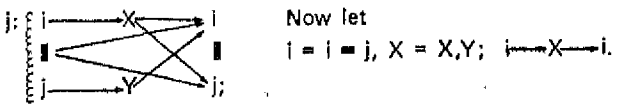


This event could, of course, be repeated indefinitely, and the trans-frontier sub-region could thus remain free of *i* and all its components. It may happen, however, that a novel SRI *j* appears in some location in the cis-frontier sub-region "spontaneously", "by chance" (as far as this theory is concerned).⁵ It may happen furthermore that this *mutation* repeatedly self-replicates (i.e., drifts, in the sense of "genetic drift") to some location *l*, at the frontier, where *i* occurs. It may happen, finally, that *j*, the mutant SRI, is cued at *l* and that its behavior at *l* brings *Y* into range at *l'*, across the frontier. The result, of course, is



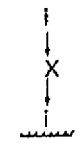
If, as is likely, *j* was exploiting *i* in the cis-frontier sub-region ($i \rightarrow X \rightarrow j$) this relation will most likely not change at the frontier, so $i \rightarrow X \rightarrow j$. If this event is repeated in the trans-frontier sub-region, *i* and *j* are the components of a

new system $i = j$; or, if *i* was a multi-component system in the cis-frontier sub-region, we could say that *j* has become a new component of system *i*, that *i* has been modified by the addition of *j*;

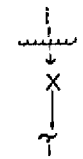


Evolutionary Events.

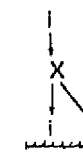
The above is an illustration of an *evolutionary event*; to wit, an ENS across a frontier. Here are a couple of others, with their preliminary and subsequent events:



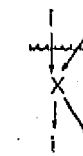
System *i* propagates/survives in a sub-region, up to a frontier, meeting S-conditions *X*.



Despite *i*'s behavior, the value of *X* across the frontier remains out of range.



Mutant SRI *j*, a passive parasite exploiting system *i* in the cis-frontier sub-region, drifts to the frontier.



i and *j* interact across the frontier to meet S-condition *X* (*Evolutionary Event*).



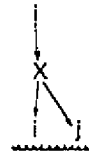
New system $i = j$ propagates/survives in the trans-frontier sub-region.

Now, let $i = i = j$; $i \rightarrow X \rightarrow i$.



In this example, *i* propagates/survives just across the frontier but no farther, because one of its Q-conditions is unmet and it thus cannot behave in the trans-frontier sub-region.

(Symbol 'i' means *i* fails to behave.)



As in the previous example, mutant SRI *j*, a passive parasite exploiting *i* in the cis-frontier sub-region, drifts to the frontier.



When the above event occurs across the frontier, *j* cues *i* in the trans-frontier sub-region (*Evolutionary Event*).

Through repetitions of that event, new system *i = j* propagates/survives in the trans-frontier sub-region. (Arrows from upper bar to lower *i* and *j* not shown.)

Now, let $i = i = j$; $i \rightarrow X \rightarrow i$.

To repeat: An evolutionary event is an ENS across a frontier.

Historical Determinism.

As a system evolves along a gradient of some variable in a region, ENSing across a series of similar frontiers and propagating into sub-regions ever more hostile to singletary SRIs, an evolutionary trend results. The system becomes ever larger, as a rule; i.e., it has ever more components SRIs. Each mutation makes roughly the same absolute difference in the behavioral repertory of the system, but the difference each makes relative to the total repertory steadily diminishes. A fairly large system of, say, several hundred SRIs is thus a powerful determinant of

its subsequent modifications. So the *history* of the system, as well as its environment and its functional relationships thereto, is an important determinant of its composition at any subsequent point.

Branching, or Specific, Evolution.

A system in a fairly large sub-region may, of course, ENS through different mutations across two (or more) frontiers of that sub-region. The "daughter" systems in the two trans-frontier sub-regions may then follow different trends in their subsequent evolution. Later on they, or (some of) their descendents, may ENS into a common sub-region, there to cooperate, co-exist, exploit each other, or compete.

Functionalism, Again.

A mutation is by definition fortuitous, a result of chance, as far as the theory under discussion is concerned. Hence it would be meaningless to say that system *i* "added *j* in order to ENS across such-and-such frontier". It would perhaps not be meaningless, however, to say that in the trans-frontier sub-region system *i* includes *j* in order that it may survive/propagate in that sub-region. That is just another way of saying that *j* remains part of *i* because of the function it performs in (for) *i*. Again, such statements seem to become increasingly meaningful as systems become larger and propagate into ever more hostile sub-regions.

PART II. IMPLICATIONS

The above account spells out many of the basic assumptions and definitions of the theory. I now present a sketchy, "whirlwind preview" of some of its likely implications, in the frank hope of stimulating some readers to join me in working out these and other implications and in interpreting and modifying the theory for purposes of understanding known phenomena and predicting others.

Frontiers.

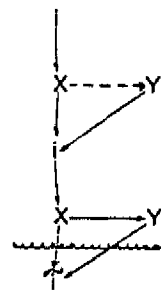
If the reader's habits of mind resemble the writer's, he/she has probably been picturing instructions propagating over stationary spatial frontiers into previously sterile (instruction-free) sub-regions in which the initial values of environmental variables remain stable at each place

and vary but little between places. While such a picture is perhaps appropriate for the tiny corner of the "primordial soup" when and where life first began, it hardly matches the turbulent hostile environments occupied by human beings or, for that matter, by any present-day living things. If we are to use Instruction-theory (as we may now call it) to account for phenomena of interest to anybody, we must recognize that frontiers are

- (1) temporal as well as spatial, placing limits on endurance/survival of instructions as well as replication/propagation
- (2) If spatial, moving as well as stationary and, if moving
 - (a) broad or narrow
 - (b) permanent, secular, or recurring
 - (c) fast or slow
- (3) artificial as well as natural, being determined by the behavior of instructions or systems, including
 - (a) other systems
 - (b) the system under consideration itself.

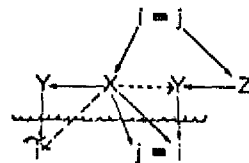
These characteristics of frontiers occur in many combinations, and each combination yields a different sort of evolutionary event and/or outcome.

Events of "Constructive" Competition



System i's behavior meets S-conditions X but by doing so produces "side-effect" Y (e.g., uses up a resource of energy or material, or pollutes its environs) which—

—at some location(s), prevents replication or endurance of i; thus i creates an artificial frontier for itself.

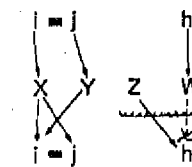


Mutant SRI overcomes "side-effect" Y through its behavioral result Z (e.g., reduces energy requirement, synthesizes material, or catabolizes pollutant). i=j now continues to propagate in sub-region. Its i-component continues to prevent replication, including replacement replication, of i-alone. i=j may eventually replace i everywhere. Now let $i = i = j$, $X = X, Z$; $i \rightarrow X \rightarrow i$.

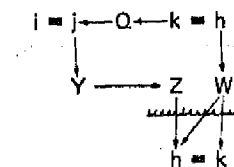
We refer to events of this kind as "constructive competition" because, while one system may replace another, no SRIs are lost. (Mutation [could be a replacement or deletion of a single SRI, but that would still be only a slight modification of i.]

The above event-process might well be repeated many times *in toto*, in which case the cumulative results would appear as a *trend*.

Events of Exploitation by Cueing.



System $i = j$ and system h co-exist in a region. h is at a frontier (e.g., a competition-frontier, in which case we would draw an arrow from W to Z).

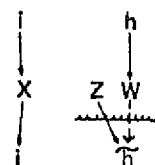


h acquires k by mutation and drift, retains k in order to cue j-component of $i = j$, since j's behavioral result, when so cued, meets S-condition Z of h.

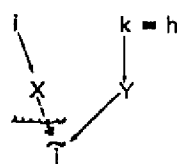
(arrow from upper bar to lower h and k not shown)

Now let $i = i = j$; $h = h = k$; $h \rightarrow Q \rightarrow i \rightarrow Y \rightarrow h$.

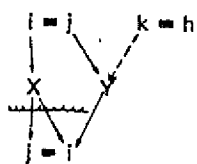
Events of Exploitation by Domestication.



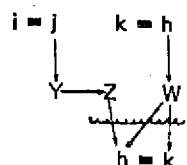
System i and system h co-exist in a region. h is at a frontier (e.g., again, a competition-frontier)



h acquires k by mutation and drift. k's behavioral result unmeets S-condition Y of i, thus creating an artificial frontier for i.



i acquires j by mutation and drift, retains j in order to meet S-condition Y (despite behavior of k). Modified system i=j ENSes over artificial frontier.



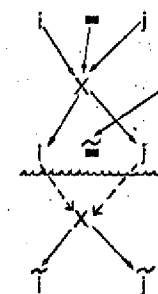
As it happens, j's behavioral result Y meets S-condition Z of h. Modified system h=k ENSes over frontier. By adopting k, h has determined a modification of i such that h exploits i (i-h), since $i \rightarrow X \rightarrow j \rightarrow Y \rightarrow Z \rightarrow h$:

(A likely subsequent event: let $h = h = k$, and go back to diagram illustrating exploitation by cueing.)

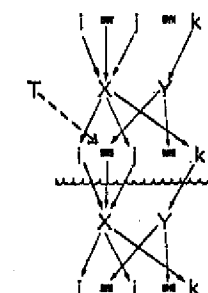
Examples of domestication, besides the obvious ones, include (1) events of domestication of the human genetic system by human cultural system(s), beginning probably in the Pliocene and extending to the Middle Pleistocene. These events were soon accompanied by reciprocal events leading to two-way domestication, or *symbiosis*. (2) events of domestication of human genetic and cultural systems, a product of the symbiotic events of (1), by suprahuman

(Inhuman?) cultural systems, since around 10,000 years B.P. Such systems can be roughly characterized as economic systems, religious systems, nationalist systems, military systems, class systems, etc. (3) events of domestication of one suprahuman cultural system by another; e.g., domestication of the guild system by the mercantile system in 15th Century Europe.

Determinants of Spatio-temporal Relationships between Instructions: II. "Strong" Determinants



Although the components of system $i = j$ replicate/endure, turbulence (T) prevents their re-occurrence in the spatio-temporal relationship necessary for cooperation, and thus prevents their further replication/endurance, creating a frontier.



Mutant k's behavioral effect Y brings or keeps i, j, and k "together" (i.e. in the necessary spatiotemporal relationship) despite T. $i = j$'s behavioral effect X, in turn, meets S-condition(s) of k. Modified system $i = j = k$ ENSes over frontier.

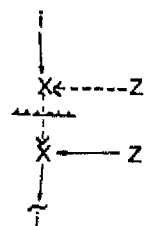
Now, $i \rightarrow X \rightarrow k \rightarrow Y \rightarrow j$, so the bar relationship is a "strong" determinant of its own re-occurrence;

it "truly" ENSes. Now let $i = i = j = k$, $X = X, Y$; $i \rightarrow X \rightarrow i$.

Examples:

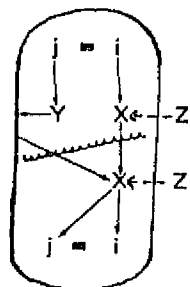
(1) $i = j$ is a primitive genetic system, afloat in the "primordial soup". T is the result of convection currents, wind, etc. k's function Y is to exude a sticky or gel-like substance which sticks to genetic SRIs, keeping them together. (2) $i = j$ is a cultural and/or genetic system in which the components i and j are carried by different organisms. T is the result of individual foraging behavior (so $X \rightarrow T$). k's function Y is to modify the gross behavior of one or both organisms so as to bring or keep them together, so i and j can interact to "X". We could call k a "sociogenic" instruction.

Organisms: Artificial Micro-environments for SRIs.



Behavior of genetic SRI *i* meets S-conditions X of *i* despite value of environmental variable Z,

but Z returns value of X out of S-condition defining range for *i*; i.e., *i* does not maintain S-condition X



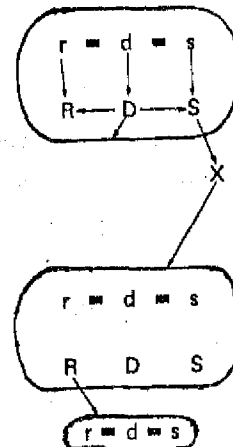
Mutant SRI *j*'s behavioral result Y is to produce a membrane around *i* and *j*. The membrane maintains S-condition X of *i* and *j*, and they are replicated.

Now, let $i = i = j$, $X = X, Y$; $i \rightarrow X \rightarrow i$

Notes: (1) The membrane is an example of a secondary structure; maintaining S-conditions of system's SRIs is its function. Hence, it is a component of the system. (2) Y is a material condition of the secondary structure (membrane); *j*'s function in $i = j$ is to meet that condition. (3) A notational convention. A membrane enclosing a system of SRIs is assumed to maintain one or more of the system's S-conditions; hence, arrows need not be drawn from membrane to SRIs or variable-symbols. (4) Another function of the membrane may be to maintain the bar-relationship between SRIs. (If so, but for the convention of (3), above, an arrow would be drawn from the membrane to the lower bar.)

Subsequent evolutionary events may well take the form of elaboration of the secondary structure (membrane), each novel SRI meeting a different material condition thereof. At some point along the way, the secondary structure can be called an organism. Whatever happens, however, the general function of the organism in the system remains the same—to maintain S-conditions of the SRIs which construct it. But each novel SRI will be adopted, of course, only if the modification it produces yields an organism which performs that general function in a certain trans-frontier sub-region. Through that process, then, the form of an organism is shaped to its function.

A very general schematic diagram of ENS of a genetic system which builds an organism would look like this: R, D, S are secondary structures for reproduction, development (ontogeny), and survival, of the organism, respectively. *r*, *d*, *s* are subsets of SRIs which "construct" those secondary structures by meeting some of their material conditions.



d constructs structures D. Structures D construct organism, furnishing materials for construction of R and S.

Structures S — including constructed instructions — meet and maintain "background" material conditions for organism; e.g., food, shelter, predator-avoidance

Structures R produce larval form of organism and "stock" it with complete set of SRIs.

Process now repeats, *ad infinitum*.

Evolutionary events take place as *r*, *d*, or *s* comes to a frontier (perhaps competition-induced), adopts a novel mutant SRI, and ENSes across that frontier.

Notes: (1) In organisms that have the right sort of central nervous system, the novel mutant SRI could just as well be cultural as genetic. (2) Cultural SRIs perform their functions by mediating between certain genetically constructed instructions; i.e., between sensory and motor apparatuses. (3) Constructed instructions, mediated genetically, culturally, and/or through conditioning, may have a sociogenic function. The social "structures" they "construct" will have the same general function as organisms—to meet and maintain the S-conditions of the SRIs which "construct" them—and they will be shaped to that function.

Further Implications.

Since replication and propagation of cultural SRIs are not immediately dependent on reproduction of the carrying organism — or, indeed, on replication of all other cultural SRIs — a system of cultural SRIs may evolve independently, crossing frontiers and domesticating the genetic system and other cultural system(s).

For instance a cultural system, which initially evolved to produce a social "structure" to bring human organisms together to meet their material conditions, may evolve to the point of enslaving them, perhaps without their even being aware of it. Such systems are "unhealthy for children and other living things." We must locate them and study them in the hope that we can effectively dismantle or alter them without destroying ourselves in the process.

I invite comments, suggestions, and criticisms of this communication. (See address on p. 1). I will reply to each individually and will share a summary of comments received by July 15, 1973, and my replies, with all correspondents prior to the Congress.

FOOTNOTES

- The logic of this relationship can be explicated by reference to a series of experiments whereby variables other than X are held as constant as possible and X is allowed to vary in and out of the specified range. If $X \rightarrow i$ is valid, the following results would be obtained:

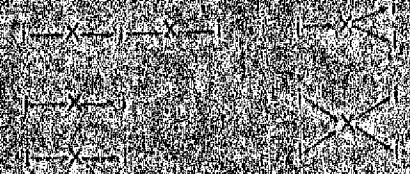
		X within specified range at l?	
		YES	NO
i occurs at l?	YES	YES ^A	NO ^C
	NO	YES ^B	YES

- A: the actual event in question falls into this category, of course.
- B: results in this category occur when some S-condition other than X is unmet.
- C: this, of course, is the crucial category for determining the validity of $X \rightarrow i$

- The same experimental logic as that in the footnote above holds here, except that the independent variable is the behavior of i:

		i behaves at l?	
		YES	NO
X within (outside of) specified range at l?	YES	YES	NO
	NO	YES	YES

3. An ENS of i repeated each time is occurring in a different spatiotemporal location, so long as behavior of i is a function of X occurrence. Thus a number of ENS of i could have a single behavioral event of i as a determinant. So each of the following diagrams represents two ENS of i .



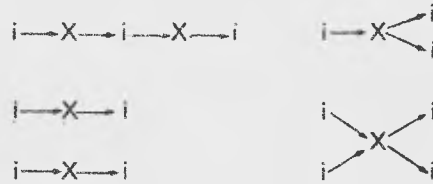
Conversely, a single ENS of i may have a number of behavioral events of i as determinants. Thus each of these diagrams represents a single ENS of i .



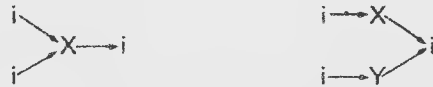
See the section entitled *The Evolutionary Equivalence of Homologous Structures*, p. 18.

- All this implies, of course, that in the old frontier sub-region the initial validity of $X \rightarrow i$ within the S-condition defining range for X so a fuller diagram for that sub-region would be $X \rightarrow i$, but the same could be said about many, many variables other than i to be consistent. In fact, we would have to represent *every* variable.
- The larger the old frontier sub-region and the longer the time elapsed, the more likely this is to occur, i.e. a mutation with a very high probability of occurrence at any one spatiotemporal location may have a very high probability of occurrence *somewhere* in a spatiotemporal sub-region.

3. An ENS of i is repeated each time i occurs in a different spatiotemporal location, so long as a behavior of i is a determinant of that occurrence. Thus, a number of ENS of i could have a single behavioral event of i as a determinant. So each of the following diagrams represents two ENS of i :



Conversely, a single ENS of i may have a number of behavioral events of i as determinants. Thus each of these diagrams represents a single ENS of i :



See the section entitled *The Evolutionary Equivalence of Homologous Instructions*, p. 6.

4. All this implies, of course, that in the cis-frontier sub-region, the initial value of Y is within the S-condition defining range for i , so a fuller diagram for that sub-region would be $i \rightarrow X \rightarrow i$; but the same could be said about many many variables other than Y ; to be consistent, in fact, we would have to represent *every* variable.
5. The larger the cis-frontier sub-region, and the longer the time elapsed, the more likely this is to occur; thus a mutation with a very tiny probability of occurrence at any one spatiotemporal location may have a very high probability of occurrence *somewhere* in a spatiotemporal sub-region.