We acknowledge the generosity of M. C. Bateson for the permission to publish in this site two chapters of *Mind and Nature* by G. Bateson.

MIND AND NATURE

A Necessary Unity

Gregory Bateson

CONTENTS

ACKNOWLEDGMENTS

The work and thought leading to this book have spread over many years, and my debts go back to include all that were acknowledged in the preface to my previous book, *Steps to an Ecology of Mind.* But I have tried to write to be understandable to those who have not read *Steps* and therefore shall acknowledge here only debts contracted since *Steps* was published.

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I INTRODUCTION *

> *Plotinus the Platonist proves by means of the blossoms and leaves that from the Supreme God, whose beauty is invisible and ineffable, Providence reaches down to the things of earth here below. He points out that these frail and mortal objects could not be endowed with a beauty so immaculate and so exquisitely wrought, did they not issue from the Divinity which endlessly pervades with its invisible and unchanging beauty all things.*
> – SAINT AUGUSTINE, *The City of God*

In June 1977, I thought I had the beginnings of two books. One I called *The Evolutionary Idea* and the other *Every Schoolboy Knows*.[*1] The first was to be an attempt to reexamine the theories of biological evolution in the light of cybernetics and information theory. But as I began to write that book, I found it difficult to write with a real audience in mind who, I could hope, would understand the formal and therefore simple presuppositions of what I was saying. It became monstrously evident that schooling in this country and in England and, I suppose, in the entire Occident was so careful to avoid all crucial issues that I would have to write a second book to explain what seemed to me elementary ideas relevant to evolution and to almost any other biological or social thinking – to daily life and to the eating of breakfast. Official education was telling people almost nothing of the nature of all those things on the seashores, and in the redwood forests, in the deserts and in the plains. Even grown-up persons with children of their own cannot give a reasonable account of concepts such as entropy, sacrament, syntax, number, quantity, pattern, linear relation, name, class, relevance, energy, redundancy, force, probability, parts, whole, information, tautology, homology, mass (either Newtonian or Christian), explanation, description, rule of dimensions, logical type, metaphor, topology, and so on. What are butterflies? What are starfish? What are beauty and ugliness?

It seemed to me that the writing out of some of these very elementary ideas could be entitled, with a little irony, "*Every Schoolboy Knows."*

But as I sat in Lindisfarne working on these two manuscripts, sometimes adding a piece to one and sometimes a piece to the other, the two gradually came together, and the product of that coming together was what I think is called a *Platonic* view.[*2] It seemed to me that in *"Schoolboy"*, I was laying down very elementary ideas about *epistemology* (see Glossary), that is, about *how we can know anything.* In the pronoun *we*, I of course included the starfish and the redwood forest, the segmenting egg, and the Senate of the United States.

And in the *anything* which these creatures variously know, I included "how to grow into five-way symmetry," how to survive a forest fire," "how to grow and still stay the same shape," "how to learn," "how to write a constitution," "how to invent and drive a car," "how to count to seven," and so on. Marvelous creatures with almost miraculous knowledges and skills.

Above all, I included "how to evolve," because it seemed to me that both evolution and learning must fit the same formal regularities or so-called laws. I was, you see, starting to use the ideas of *"Schoolboy"* to reflect, not upon our own knowing, but upon that *wider knowing* which is the glue holding together the starfishes and sea anemones and redwood forests and human committees.

My two manuscripts were becoming a single book because there is a single knowing which characterizes evolution as well as *aggregates* of humans, even though committees and nations may seem stupid to two-legged geniuses like you and me.

I was transcending that line which is sometimes supposed to enclose the human being. In other words, as I was writing, mind became, for me, a reflection of large parts and many parts of the natural world outside the thinker.

On the whole, it was not the most crudest, the simplest, the most animalistic and primitive aspects of the human species that were reflected in the natural phenomena. It was, rather, the more complex, the aesthetic, the intricate, and the elegant aspects of people that reflected nature. It was not my greed, my purposiveness, my so-called "animal," so-called "instincts," and so forth that I was recognizing on the other side of that mirror, over there in "nature." Rather, I was seeing there the roots of human symmetry, beauty and ugliness, aesthetics, the human being’s very aliveness and little bit of wisdom. His wisdom, his bodily grace, and even his habit of making beautiful objects are just as "animal" as his cruelty. After all, the very word "animal" means "endowed with mind or spirit *(animus)."*

Against this background, those theories of man that start from the most animalistic and maladapted psychology turn out to be improbable first premises from which to approach the psalmist’s question: "Lord, What is man?"

I never could accept the first step of the Genesis story: " In the beginning the earth was without form and void." That primary *tabula rasa* would have set a formidable problem in thermodynamics for the next billion years. Perhaps the earth never was any more a *tabula rasa* than is, a human zygote – a fertilized egg.

It began to seem that the old-fashioned and still-established ideas about epistemology, especially human epistemology, were a reflection of an obsolete physics and contrasted in a curious way with the little we seem to know about living things. It was as if members of the species, man, were supposed to be totally unique and totally materialistic against the background of a living universe which was generalized (rather than unique) and spiritual (rather than materialistic).

There seems to be something like a Gresham’s law of cultural evolution according to which the oversimplified ideas will always displace the sophisticated and the vulgar and hateful will always displace the beautiful.

And yet the beautiful persists.

It began to seem as if organized matter – and I know nothing about unorganized matter, if there be any – in even such a simple set of relations as exists in a steam engine with a governor was wise and sophisticated compared with the picture of human spirit that orthodox materialism and a large part of orthodox religion currently drew.

The germ of these ideas had been in my mind since I was a boy. But let me start from two contexts in which these thoughts began to insist on utterance: In the 1950’s, I had two teaching tasks. I was teaching psychiatric residents at a Veterans Administration mental hospital in Palo Alto and young beatniks in the California School of Fine Arts in San Francisco. I want to tell you how those two courses commenced, how I approached those two contrasting audiences. If you put these two first lectures side by side, you will see what I am trying to say.

To the psychiatrists, I presented a challenge in the shape of a small exam paper, telling them that by the end of the course the should understand the questions on it. Question 1 asked for brief definitions of (a) "sacrament" and (b) "entropy."

The young psychiatrists in the 1950s were, in general, unable to answer *either* question. Today, a few more could begin to talk about entropy (see Glossary). And I suppose there are still some Christians who could say what a sacrament is?

I was offering my class the core notions of 2,500 years of thought about religion and science. I felt that if they were going to be doctors (medical doctors) of the human soul, they should at least have a foot on each side of the ancient arguments. They should be familiar with the central ideas of both religion and science.

For the art students, I was more direct. It was a small group of about ten to fifteen students, and I knew that I would be walking into an atmosphere of skepticism bordering on hostility. When I entered it was clear that I was expected to be an incarnation of the devil, who would argue for the common sense of atomic warfare and pesticides. In those days (and even today?), science was believed to be "value-free" and not guided by "emotions."

I was prepared for that. I had two paper bags, and the first of these I opened, producing a freshly cooked crab, which I placed on the table. I then challenged the class somewhat as follows: "I want you to produce arguments which will convince me that this objects is the remains of a living thing. You may imagine, if you will, that your are Martians and that on Mars you are familiar with living things, being indeed yourselves alive. But, of course, you have never seen crabs or lobsters. A number of objects like this, many of them fragmentary, have arrived, perhaps by meteor. You are to inspect them and arrive at the conclusion that they are the remains of living things. How would you arrive at that conclusion?"

Of course, the question set for the psychiatrists was the *same question* as that which I set for the artists: Is there are biological species of entropy?

Both questions concerned the underlying notion of a dividing line between the world of the living (where *distinctions* are drawn and *difference* can be a cause) and the world of nonliving billiard balls and galaxies (where forces and impacts are the "causes" of events). These are the two worlds that Jung (following the Gnostics) calls *creatura* (the living) and *pleroma* (the nonliving).[*3] I was asking: What is the difference between the physical world of pleroma, where forces and impacts provide sufficient basis of explanation, and the *creatura*, where nothing can be understood until *differences* and *distinctions* are invoked?

In my life, I have put the descriptions of sticks and stones and billiard balls and galaxies in one box, the pleroma, and have left them alone. In the other box, I put living things: crabs, people, problems of beauty, and problems of difference. The contents of the second box are the subject of this book.

I was griping recently about the shortcomings of occidental education. It was in a letter to my fellow regents of the University of California, and the following phrase crept into my letter:

> *"Break the pattern which connects the items of learning and you necessarily destroy all quality."*

I offer you the phrase *the pattern which connects* as a synonym, another possible title for this book.

The pattern which connects. Why do schools teach almost nothing of the pattern which connects? Is it that teachers know that they carry the kiss of death which will turn to tastelessness whatever they touch or teach anything of real-life importance? Or is it that they carry the kiss of death *because* they dare not teach anything of real-life importance? What's wrong with them?

What pattern connects the crab to the lobster and the orchid to the primrose and all the four of them to me? And me to you? And all the six of us to the amoeba in one direction and to the back-ward schizophrenic in another?

I want to tell you why I have been a biologist all my life, what it is that I have been trying to study. What thoughts can I share regarding the total biological world in which we live and have our being? How is it put together?

What now must be said is difficult, appears to be quite *empty,* and is of very great and deep importance to you and to me. At this historic juncture, I believe it to be important to the survival of the whole biosphere which you know is threatened.

What is the pattern which connects all the living creatures?

Let me go back to my crab and my class of beatniks. I was very lucky to be teaching people who were not scientists and the bias of whose minds was even antiscientific. All untrained as they were, their bias was aesthetic. I would define that word, for the moment, by saying that they were *not* like Peter Bly, the character of whom Wordsworth sang

> *A primrose by the river's brim*
> *A yellow primrose was to him;*
> *And It was nothing more.*

Rather, they would meet the primrose with *recognition* and *empathy*. By *aesthetic,* I mean responsive to *the pattern which connects.* So you see, I was lucky. Perhaps by coincidence, I faced them with what was (though I knew it not) an aesthetic question: *How are you related to this creature? What pattern connects you to it?*

By putting them on an imaginary planet, "Mars," I stripped them of all thought of lobsters, amoebas, cabbages, and so on and forced the diagnosis of life back into identification with living self: "*You* carry the bench marks, the criteria, with which you could look at the crab to find that it, too, carries the same marks." My question was much more sophisticated than I knew.

So they looked at the crab. And first of all, they came up with the observation that it is *symmetrical;* that is, the right side resembles the left.

"Very good. You mean it's *composed,* like a painting?" (No response.)

Then they observed that one claw was bigger than the other. So it was *not* symmetrical.

I suggested that if a number of these objects had come by meteor, they would find that in almost all specimens it was the same side (right or left) that carried the bigger claw. (No response "What's Bateson getting at?")

Going back to symmetry somebody said that *"yes, one claw is bigger than the other, but both claws are made of the same parts."*

Ah! What a beautiful and noble statement that is, how the speaker politely flung into the trash can the idea that *size* could be of primary or profound importance and went after the *pattern which connects.* He discarded an asymmetry in size in favor of a deeper symmetry in formal relations.

Yes, indeed, the two claws are characterized (ugly word) by embodying *similar relations between parts.* Never quantities, always shapes, forms, and relations. This was, indeed, something that characterized the crab as a member of the *creature,* a living thing.

Later, it appeared that not only are the two claws built on the same "ground plan," (i.e., upon corresponding sets of relations between corresponding parts) but that these relations between corresponding parts extend down the series of the walking legs. We could recognize in every leg pieces that corresponded to the pieces in the claw.

And in your own body, of course, the same sort of thing is true. Humerus in the upper arm correspond to femur in the thigh, and radius-ulna corresponds to tibia-fibula; the carpals in the wrist correspond to tarsals in the foot; fingers correspond to toes.

The anatomy of the crab is repetitive and rhythmical. It is, like music, repetitive with modulation. Indeed, the direction from head toward tail corresponds to a sequence in time: In embryology, the head is older than the tail. A flow of information is possible, from front to rear.

Professional biologists talk about phylogenetic *homology* (see Glossary) for that *class* of facts of which one example is the formal resemblance between my limb bones and those of a horse. Another example is the formal resemblance between the appendages of a crab and those of a lobster.

That is one class of facts. Another (somehow similar?) class of facts is what they call *serial homology*. One example is the rhythmic repetition with change from appendage to appendage down the length of the breast (crab or man); another (perhaps not quite comparable because of the difference in relation to time) would be the bilateral symmetry of the man or crab.*4

Let me start again. The parts of a crab are connected by various patterns of bilateral symmetry, of serial homology, and so on. Let us call these patterns within the individual growing crab *first-order connections*. But now we look at crab and lobster and we again find connection by pattern. Call it *second-order connection*, or phylogenetic homology.

Now we look at man or horse and find that, here again, we can see symmetries and serial homologies. When we look at the tow together, we find the same cross-species sharing of pattern with a difference (phylogenetic homology). And, of course, we also find the same discarding of magnitudes in favor of shapes, patterns, and relations. In other words, as this distribution of formal resemblances is spelled out, it turns out that gross anatomy exhibits three levels or logical types of descriptive propositions:

1. The parts of any member of *Creatura* are to be compared with other parts of the same individual to give first-order connections.
2. Crabs are to be compared with lobsters or men with horses to find similar relations between parts (i.e., to give second-order connections).
3. The *comparison* between crabs and lobsters is to be compared with the comparison between man and horse to provide third-order connections.

We have constructed a ladder of how to think about – about what? Oh, yes, the pattern which connects.

My central thesis can now be approached in words: The *pattern which connects is a metapattern*. It is a pattern of patterns. It is that metapattern which defines the vast generalization that, indeed, *it is patterns which connect*.

I warned some pages back that we would encounter emptiness, and indeed it is so. Mind is empty; it is nothing. It exists only in its ideas, and these again are no-things. Only the ideas are immanent, embodied in their examples. And the examples are, again, no-things. The claw, *as an example*, is not the *Ding an sich*; it is precisely *not* the "thing in itself." Rather, it is what mind makes of it, namely an *example* of something or other.

Let me go back to the classroom of young artists.

You will recall that I had *two* paper bags. In one of them was the crab. In the other I had a beautiful large conch shell. By what token, I asked them, could they know that the spiral shell had been part of a living thing?

When she was about seven, somebody gave my daughter Cathy a cat's-eye mounted as a ring. She was wearing it, and I asked her what it was. She said it was a cat’s-eye.

I said, "But what *is* it?"

"Well, I know it’s not the eye of a cat. I guess it’s some sort of stone."

I said, "Take it off and look at the back of it."

She did that and exclaimed, "Oh, it’s got a spiral on it! It must have belonged to something alive."

Actually, these greenish disks are the opercula (lids) of a species of tropical marine snail. Soldiers brought lots of them back from the Pacific at the end of World War II.

Cathy was right in her major premise that all spirals in this world except whirlpools, galaxies, and spiral winds are, indeed made by living things. There is an extensive literature on this subject, which some readers may be interested in looking up (the key words are *Fibonacci series* and *golden section*).

What comes out of all this is that a spiral is a figure that *retains its shape (i.e., its proportions) as it grows* in one dimension by addition at the open end. You see, there are no truly static spirals.

But the class had difficulty. They looked for all the beautiful formal characteristics that they had joyfully found in the crab. They had the idea that formal symmetry, repetition of parts, modulated repetition, and so on were what teacher wanted. But the spiral was not bilaterally symmetrical; it was not segmented.

They had to discover (a) that all symmetry and segmentation were somehow a result, a payoff from, the fact of growth; and (b) that growth makes its formal demands; and (c) that one of these is satisfied (in a mathematical, an ideal, sense) by spiral form.

So the conch shell carries the snail’s *prochronism* – its record of how, *in its own past*, it successively solved a formal problem in pattern formation (see Glossary). It, too, proclaims its affiliation under that pattern of patterns which connects.

So far, all the examples that I have offered – the patterns which have membership in the pattern which connects, the anatomy of crab and lobster, the conch, and man and horse – have been superficially static. The examples have been the frozen shapes, results of regularized change, indeed, but themselves finally fixed, like the figures in Keats’ "Ode on a Grecian Urn":

> *Fair youth, beneath the trees, thou can’st not leave*
> *Thy song, not ever can those trees be bare;*
> *Bold lover, never never canst thou kiss,*
> *Though winning near the goal – yet do not grieve;*
> *She cannot fade, though thou hast not thy bliss,*

Forever wilt thou love, and she be fair!

We have been trained to think of patterns, with the exception of those of music, as fixed affairs. It is easier and lazier that way but, of course, all nonsense. In truth, the right way to begin to think about the pattern which connects is to think of it as *primarily* (whatever that means) a dance of interacting parts and only secondarily pegged down by various sorts of physical limits and by those limits which organisms characteristically impose.

There is a story which I have used before and shall use again: A man wanted to know about mind, not in nature, but in his private large computer. He asked it (no doubt in his best Fortran), "Do you compute that you will ever think like a human being?" The machine then set to work to analyze its own computational habits. Finally, the machine printed its answer on a piece of paper, as such machines do. The man ran to get the answer and found, neatly typed, the words:

THAT REMINDS ME OF A STORY

A story is a little knot or complex of that species of connectedness which we call *relevance*. In the 1960s, students were fighting for "relevance," and I would assume that any A is relevant to any B if both A and B are parts or components of the same "story".

Again we face connectedness at more than one level:

First, connection between A and B by virtue of their being components in the same story.

And then, connectedness between people in that all think in terms of stories. (For surely the computer was right. This is indeed how people think.)

Now I want to show that whatever the word *story* means in the story which I told you, the fact of thinking in terms of stories does not isolate human beings as something separate from the starfish and the sea anemones, the coconut palms and the primroses. Rather, if the world be connected, if I am at all fundamentally right in what I am saying, then *thinking in terms of stories* must be shared by all mind of minds, whether ours or those of redwood forests and sea anemones.

Context and relevance must be characteristic not only of all so-called behavior (those stories which are projected out into "action"), but also of all those internal stories, the sequences of the building up of the sea anemone. Its embryology must be somehow made of the stuff of stories. And behind that, again, the evolutionary process through millions of generations whereby the sea anemone, like you and like me, came to be – that process, too, must be of the stuff of stories. There must be relevance in every step of phylogeny and among the steps.

Prospero says, "We are such stuff as dreams are made on," and surely he is nearly right. But I sometimes think that dreams are only fragments of that stuff. It is as if the stuff of which we are made were totally transparent and therefore imperceptible and as if the only appearances of which we can be aware are cracks and planes of fracture in that transparent matrix. Was this what Plotinus meant by an "invisible and unchanging beauty which pervades all things?"

What is a story that it may connect the As and Bs, its parts? And is it true that the general fact that parts are connected in this way is at the very root of what it is to be alive? I offer you the notion of *context*, of *pattern through time.*

What happens when, for example, I go to a Freudian psychoanalyst? I walk into and create something which we will call a *context* that is at least symbolically (as a piece of the world of ideas) limited and isolated by closing the door. The geography of the room and the door is used as a representation of some strange, nongeographic message.

But I come with stories – not just supply of stories to deliver to the analyst but stories built into my very being. The patterns and sequences of childhood experience are built into me. Father did so and so; my aunt did such and such; and what they did was outside my skin. But whatever it was that I learned, my learning happened within my experiential sequence of what those important others – my aunt, my father – did.

Now I come to the analyst, this newly important other who must be viewed as a father (or perhaps antifather) because nothing has meaning except it be seen as in come context. This viewing is called *transference* and is a general phenomenon in human relations. It is a universal characteristic of all interaction between persons because, after all, the shape of what happened between you and me yesterday carries over to shape how we respond to each other today. And that shaping is, in principle, a *transference* from past learning.

This phenomenon of transference exemplifies the truth of the computer’s perception that we think in stories. The analyst must be stretched or shrunk onto the Procrustean bed of the patient’s childhood stories. But also, by referring to psychoanalysts, I have narrowed the idea of "story." I have suggested that it has something to do with *context*, a crucial concept, partly undefined and therefore to be examined.

And "context" is linked to another undefined notion called "meaning." Without context, words and actions have no meaning at all. This is true not only of human communication in words but also of all communication whatsoever, of all mental process, of all mind, including that which tells the sea anemone how to grow and the amobea what he should do next.

I am drawing an analogy between context in the superficial and partly conscious business of personal relations and context in the much deeper, more archaic processes of embryology and homology. I am asserting that whatever the word *context* means, it is an appropriate word, the *necessary* word, in the description of all these distantly related processes.

Let us look at homology backwards. Conventionally, people prove that evolution occurred by citing cases of homology. Let me do the reverse. Let me assume that evolution occurred and go on to ask about the nature of homology. Let us ask what some organ *is* according to the light shed upon it by evolutionary theory.

What is an elephant's trunk? What is it phylogenetically? What did genetics tell it to be?

As you know, the answer is that the elephant's trunk is his "nose." (Even Kipling knew!) And I put the word "nose" in quotation marks because the trunk is being defined by an internal process of communication in growth. The trunk is a "nose" by a process of communication: it is the context of the trunk that identifies it as a nose. That which stands between two eyes and north of a mouth is a "nose," and that is that.

It is the *context* that fixes the meaning, and it must surely be the receiving context that provides meaning for the genetic instructions. When I call that a "nose" and this a "hand" I am quoting – or misquoting – the developmental instructions in the growing organism, and quoting what the tissues which received the message thought the message intended.

There are people who would prefer to define noses by their "function" – that of smelling. But if you spell out those definitions, you arrive at the same place using a temporal instead of a spatial context. You attach meaning to the organ by seeing it as playing a given part in sequences of interaction between creature and environment. I call that a *temporal* context. The temporal classification cross-cuts the spatial classification of contexts. But in embryology, the first definition must always be in terms of formal relations. The fetal trunk cannot, in general, smell anything. Embryology is *formal*.

Let me illustrate this species of connection, this connecting pattern, a little further by citing a discovery of Goethe's. He was a considerable botanist who had great ability in recognizing the nontrivial (i.e., in recognizing the patterns that connect). He straightened out the vocabulary of the gross comparative anatomy of flowering plants. He discovered that a "leaf" is not satisfactorily defined as "a flat green thing" or a "stem" as "a cylindrical thing." The way to go about the definition – and undoubtedly somewhere deep in the growth processes of the plant, this is how the matter is handled – is to note that buds (i.e., baby stems) form in the angles of leaves. From that, the botanist constructs the definitions on the basis of the relations between stem, leaf, bud, angle, and so on.

> *"A stem is that which bears leaves."*
> *"A leaf is that which has a bud in its angle."*
> *"A stem is what was once a bud in that position,"*

All that is – or should be – familiar. But the next step is perhaps new.

There is a parallel confusion in the teaching of language that has never been straightened out. Professional linguists nowadays may know what's what, but children in school are still taught nonsense. They are told that a "noun" is the "name of a person, place, or thing," that a "verb" is "an action word," and so on. That is, they are taught at a tender age that the way to define something is by what it supposedly *is* in itself, not by its relation to other things.

Most of us can remember being told that a noun is "the name of a person, place, or thing." And we can remember the utter boredom of parsing or analyzing sentences. Today all that should be changed. Children could be told that a noun is a word having a certain relationship to a predicate. A verb has a certain relation to a noun, its subject. And so on. Relationship could be used as basis for definition, and any child could then see that there is something wrong with the sentence "Go' is a verb."

I remember the boredom of analyzing sentences and the boredom later, at Cambridge, of learning comparative anatomy. Both subjects, as taught, were torturously unreal. We *could* have been told something about the pattern which connects: that all communication necessitates context, that without context, there is no meaning, and that contexts confer meaning because there is classification of contexts. The teacher could have argued that growth and differentiation must be controlled by communication. The shapes of animals and plants are transforms of messages. Language is itself a form of communication. The structure of the input must somehow be reflected as structure in the output. Anatomy *must* contain an analogue of grammar because all anatomy is a transform of message material, which must be contextually shaped. And finally, *contextual shaping* is only another term for *grammar*.

So we come back to the patterns of connection and the more abstract, more general (and most empty) proposition that, indeed, there is a pattern of patterns of connection.

This book is built on the opinion that we are parts of a living world. I have placed as epigraph at the head of this chapter a passage from Saint Augustine in which the saint's epistemology is clearly stated. Today such a statement evokes nostalgia. Most of us have lost that sense of unity of biosphere and humanity which would bind and reassure us all with an affirmation of beauty. Most of us do not today believe that whatever the ups and downs of detail within our limited experience, the larger whole is primarily beautiful.

We have lost the core of Christianity. We have lost Shiva, the dancer of Hinduism whose dance at the trivial level is both creation and destruction but in whole is beauty. We have lost Abraxas, the terrible and beautiful god of both day and night in Gnosticism. We have lost totemism, the sense of parallelism between man's organization and that of the animals and plants. We have lost even the Dying God.

We are beginning to play with ideas of ecology, and although we immediately trivialize these ideas into commerce or politics, there is at least an impulse still in the human breast to unify and thereby sanctify the total natural world, of which we are.

Observe, however, that there have been, and still are, in the world many different and even contrasting epistemologies which have been alike in stressing an ultimate unity and, although this is less sure, which have also stressed the notion that ultimate unity is *aesthetic*. The uniformity of these views gives hope that perhaps the great authority of quantitative science may be insufficient to deny an ultimate unifying beauty.

I hold to the presupposition that our loss of the sense of aesthetic unity was, quite simply, an epistemological mistake. I believe that that mistake may be more serious that all the minor insanities that characterize those older epistemologies which agreed upon the fundamental unity.

A part of the story of our loss of the sense of unity has been elegantly told in Lovejoy's *Great Chain of Being*,[*5] which traces the story form classical Greek philosophy to Kant and the beginnings of German idealism in the eighteenth century. This is the story of the idea that the world is/was timelessly created *upon deductive logic*. The idea is clear in the epigraph from *The City of God*. Supreme Mind, or Logos, is at the head of the deductive chain. Below that are the angels, then people, then apes and so on down to the plants and stones. All is in deductive order and tied into that order by a premise which prefigures our second law of thermodynamics. The premise asserts that the "more perfect" can never be generated by the "less perfect."

In the history of biology, it was Lamarck [*6] who inverted the great chain of being. By insisting that mind is immanent in living creatures and could determine their transformations, he escaped from the negative directional premise that the perfect must always precede the imperfect. He then proposed a theory of "transformism" (which we would call *evolution*) which started from infusoria (protozoa) and marched upward to man and woman.

The Lamarckian biosphere was still a *chain*. The unity of epistemology was retained in spite of a shift in emphasis from transcendent Logos to immanent mind.

The fifty years that followed saw the exponential rise of the Industrial Revolution, the triumph of Engineering over Mind, so that the culturally appropriate epistemology for the *Origin of Species* (1859) was an attempt to exclude mind as an explanatory principle. Titling at a windmill.

There were protests much more profound than the shrieks of the Fundamentalists. Samuel Butler, Darwin's ablest critic, saw that the denial of mind as an explanatory principle was intolerable and tried to take evolutionary theory back to Lamarckism. But that would not do because of the hypothesis (shared even by Darwin) of the "inheritance of acquired characteristics." This hypothesis – that the responses of an organism to its environment could affect the genetics of the offspring – was an error.

I shall argue that this error was specifically an epistemological error in logical typing and shall offer a definition of *mind* very different from the notions vaguely held by both Darwin and Lamarck. Notably, I shall assume that thought resembles evolution in being a stochastic (see Glossary) process.

In what is offered in this book, the hierarchic structure of thought, which Bertrand Russell called *logical typing*, will take the place of the hierarchic structure of the Great Chain of Being and an attempt will be made to propose a sacred unity of the biosphere that will contain fewer epistemological errors that the versions of that sacred unity which the various religions of history have offered. What is important is that, right or wrong, the epistemology shall be *explicit.* Equally explicit criticism will then be possible.

So the immediate task of this book is to construct a picture of how the world is joined together in its mental aspects. How do ideas, information, steps of logical or pragmatic consistency, and the like fit together? How is logic, the classical procedure for making chains of ideas, related to an outside world of things and creatures, parts and wholes? Do ideas really occur in chains, or is this lineal (see Glossary) structure imposed on them by scholars and philosophers? How is the world of logic, which eschews "circular argument," related to a world in which circular trains of causation are the rule rather than the exception?

What has to be investigated and described is a vast network or matrix of interlocking message material and abstract tautologies, premises, and exemplifications.

But, as of 1979, there is no conventional method of describing such a tangle. We do not know even where to begin.

Fifty years ago, we would have assumed that the best procedures fur such a task would have been either logical or quantitative, or both. But we shall see as every schoolboy ought to know that logic is precisely unable to deal with recursive circuits without generating paradox and that quantities are precisely not the stuff of complex communicating systems.

In other words, logic and quantity turn out to be inappropriate devices for describing organisms and their interactions and internal organization. The particular nature of this inappropriateness will be exhibited in due course, but for the moment, the reader is asked to accept as true the assertion that, as of 1979, there is no conventional way of explaining or even describing the phenomena of biological organization and human interaction.

John Von Neumann pointed out thirty years ago, in his *Theory of Games*, that the behavioral sciences lack any reduced model which would do for biology and psychiatry what the Newtonian particle did for physics.

There are however, a number of somewhat disconnected pieces of wisdom that will aid the task of this book. I shall therefore adopt the method of Little Jack Horner, pulling out plums one after the other and exhibiting them side by side to create an array from which we can go on to list some fundamental criteria of mental process.

In Chapter 2, "Every Schoolboy Knows," I shall gather for the reader some examples of what I regard as simple necessary truths – necessary first if the schoolboy is ever to learn to think and then again necessary because, as I believe, the biological world is geared to these simple propositions.

In Chapter 3 I shall operate in the same way but shall bring to the reader's attention a number of cases in which two or more information sources come together to give information of a sort different from what was in either source separately.

At present, there is no existing science whose special interest is the combining of pieces of information. But I shall argue that the evolutionary process must depend upon such double increments of information. Every evolutionary step is an addition of information to an already existing system. Because this is so, the combinations, harmonies, and discords between successive pieces and layers of information will present many problems of survival and determine many directions of change.

Chapter 4, "The Criteria of Mind," will deal with the characteristics that in fact always seem to be combined in our earthly biosphere to make mind. The remainder of the book will focus more narrowly on problems of biological evolution.

Throughout, the thesis will be that it is possible and worthwhile to *think* about many problems of order and disorder in the biological universe and that we have today a considerable supply of tools of though which we do not use, partly because – professors and schoolboys alike – we are ignorant of many currently available insights and partly because we are unwilling to accept the necessities that follow from a clear view of the human dilemmas.

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* A large part of this chapter was delivered as a lecture at the Cathedral of Saint John the Divine in New York on November 17, 1977 [back to text]

*[1] A favorite phrase of Lord Macaulay’s. He is credited with, "Every schoolboy knows who imprisoned Montezuma, and who strangled Atahualpa." [back to text]

*[2] Plato’s most famous discovery concerned the "reality" of ideas. We commonly think that a dinner plate is "real" but that its circularity is "only an idea." But Plato noted, first, that the plate is not truly circular and, second, that the world can be perceived to contain a very large number of objects which simulate, approximate, or strive after "circularity." He therefore asserted that "circularity" is *ideal* (the adjective derived form *idea*) and that such ideal components of the universe are the real explanatory basis for its forms and structure. For him, as for William Blake and many others, that "Corporal Universe" which our newspapers consider "real" was some sort of spin-off from the truly real, namely the forms and ideas. In the beginning was the idea. [back to text]

*[3] C.G. Jung, *Septem Sermones ad Mortuos* (London: Stuart & Watkins, 1967). [back to text]

*[4] In the serial case it is easy to imagine that each anterior segment may give information to the next segment which is developing immediately behind it. Such information might determine orientation, size, and even shape of the new segment. After all, the anterior is also antecedent in time and could be the quasi-logical antecedent or model for its successor. The relation between anterior and posterior would

then be asymmetrical and complementary. It is conceivable and even expectable that the symmetrical relation between right and left is doubly asymmetrical, i.e., that each has some complementary control over the development of the other. The pair would then constitute a circuit of reciprocal control. It is surprising that we have almost no knowledge of the vast system of communication which must surely exist to control growth and differentiation. [back to text]

*[5] Arthur O. Lovejoy, *The Great Chain of Being: A Study of the History of an Idea* (Cambridge: Harvard University Press, 1936). [back to text]

*[6] J.-B. Lamarck, *Philosophie Zoologique* (1809) translated as [Zoological philosophy: An exposition with regard to the natural history of animals, trans. Hugh Elliot] (New York & London: Hafner Press, 1963). [back to text]

II Every Schoolboy Knows …

III Multiple Versions of the World

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II EVERY SCHOOLBOY KNOWS …

By education most have been misled;
So they believe, because they so were bred.
The priest continues what the nurse began,
And thus the child imposes on the man.
- John Dryden, *The Hind and the Panther*

Science, like art, religion, commerce, warfare, and even sleep, is based on *presuppositions*. It differs, however, from most other branches of human activity in that not only are the pathways of scientific thought determined by the presuppositions of the scientists but their goals are the testing and revision of old presuppositions and the creation of new.

In this latter activity, it is clearly desirable (but not absolutely necessary) for the scientist to know consciously and be able to state his own presuppositions. It is also convenient and necessary for scientific judgment to know the presuppositions of colleagues working in the same field. Above all, it is necessary for the reader of scientific matter to know the presuppositions of the writer.

I have taught various branches of behavioral biology and cultural anthropology to American students, ranging from college freshmen to psychiatric residents, in various schools and teaching hospitals, and I have encountered a very strange gap in their thinking that springs from a lack of certain *tools* of thought. This lack is rather equally distributed at all levels of education, among students of both sexes and among humanists as well as scientists. Specifically, it is lack of knowledge of the presuppositions not only of science but also of everyday life.

This gap is, strangely, less conspicuous in two groups of students that might have been expected to contrast strongly with each other: the Catholics and the Marxists. Both groups have thought about or have been told a little about the last 2,500 years of human thought, and both groups have some recognition of the importance of philosophic, scientific, and epistemological presuppositions. Both groups are difficult to teach because they attach such great importance to "right" premises and presuppositions that heresy becomes for them a threat of excommunication. Naturally, anybody who feels heresy to be a danger will devote some care to being conscious of his or her own presuppositions and will develop a sort of connoisseurship in these matters.

Those who lack all idea that it is possible to be wrong can learn nothing except know-how.

The subject matter of this book is notably close to the core of religion and to the core of scientific orthodoxy. The presuppositions – and most students need some instruction in what a presupposition looks like – are matters to be brought out into the open.

There is, however, another difficulty, almost peculiar to the American scene. Americans are, no doubt, as rigid in their presuppositions as any other people (and as rigid in these matters as the writer of this book), but they have a strange response to any articulate statement of presupposition. Such statement is commonly assumed to be hostile or mocking or – and this is the most serious – is heard to be *authoritarian*. It thus happens that in this land founded for the freedom of religion, the teaching of religion is outlawed in the state educational system. Members of weakly religious families get, of course, no religious training from any source outside the family.

Consequently, to make any statement of premise or presupposition in a formal and articulate way is to challenge the rather subtle resistance, not of contradiction, because the hearers do not know the contradictory premises nor how to state them, but of the cultivated deafness that children use to keep out the pronouncements of parents, teachers, and religious authorities.

Be all that as it may, I believe in the importance of scientific presuppositions, in the notion that there are better and worse ways of constructing scientific theories, and in insisting on the articulate statement of presuppositions so that they may be improved.

Therefore, this chapter is devoted to a list of presuppositions, some familiar, some strange to readers whose thinking has been protected from the harsh notion that some propositions are simply wrong. Some tools of thought are so blunt that they are almost useless; others are so sharp that they are dangerous. But the wise man will have the use of both kinds.

It is worthwhile to attempt a tentative recognition of certain basic presuppositions which all *minds* must share or, conversely, to define mind by listing a number of such basic communicational characteristics.

1. SCIENCE NEVER PROVES ANYTHING

Science sometimes *improves* hypothesis and sometimes *disproves* them. But *proof* would be another matter and perhaps never occurs except in the realms of totally abstract tautology. We can sometimes say that *if* such and such abstract suppositions or postulates are given, *then* such and such abstract suppositions or postulates are given, *then* such and such must follow absolutely. But the truth about what can be *perceived* or arrived at by induction from perception is something else again.

Let us say that truth would mean a precise correspondence between out description and what we describe or between our total network of abstractions and deductions and some total understanding of the outside world. Truth in this sense is not obtainable. And even if we ignore the barriers of coding, the circumstance that our description will be in words or figures or pictures but that what we describe is going to be in flesh and blood and action – even disregarding that hurdle of translation, we shall never be able to claim final knowledge of anything whatsoever.

A conventional way of arguing this matter is somewhat as follows: Let us say that I offer you a series – perhaps of number, perhaps of other indications – and that I provide the presupposition that the series is ordered. For the sake of simplicity, let it be a series of numbers:

2, 4, 6, 8, 10, 12

Then I ask you, "What is the next number in this series?" You will probably say, "14."

But if you do, I will say, "Oh, no. The next number is 27." In other words, the generalization to which you jumped from the data given in the first instance – that the series was the series of even numbers – was proved to be wrong or only approximate by the next event.

Let us pursue the matter further. Let me continue my statement by creating a series as follows:

2, 4, 6, 8, 10, 12, 27, 2, 4, 6, 8, 10, 12, 27, 2, 4, 6, 8, 10, 12, 27, …

Now if I ask you to guess the next number, you will probably say, "2." After all, you have been given tree repetitions of the sequence from 2 to 27; and if you are a good scientist, you will be influenced by the presupposition called *Occam's razor,* or the *rule of parsimony:* that is, a preference for the simplest assumption that will fit the facts. On the basis of simplicity you will make the next prediction. But those facts – what are they? They are not, after all, available to you beyond the end of the (possibly incomplete) sequence that has been given.

You *assume* that you can predict, and indeed I suggested this presupposition to you. But the only basis you have is your (trained) preference for the simpler answer and your trust that my challenge indeed meant that the sequence was incomplete and ordered.

Unfortunately (or perhaps fortunately), it is so that the next fact is never available. All you have is the hope of simplicity, and the next fact may always drive you to the next level of complexity.

Or let us say that for any sequence of numbers I can offer, there will always be a few ways of describing that sequence which will be simple, but there will be an *infinite* number of alternative ways not limited by the criterion of simplicity.

Suppose the numbers are represented by letters:

x, w, p, n

and so on. Such letters could stand for any numbers whatsoever, even fractions. I have only to repeat the series three or four times in some verbal or visual or other sensory form, even in the forms of pain or kinesthesia, and you will begin to perceive pattern in what I offer you. It will become in your mind – and in mine – a theme, and it will have aesthetic value. To that extent, it will be familiar and understandable.

But the pattern may be changed or broken by addition, by repetition, by anything that will force you to a new perception of it, and these changes can never be predicted with absolute certainty because they have not yet happened.

We do not know enough about how the present will lead into the future. We shall never be able to say, "Ha! My perception, my accounting for that series, will indeed cover its next and future components," or " Next time I meet with these phenomena, I shall be able to predict their total course."

Prediction can never be absolutely valid and therefore science can never *prove* some generalization or even *test* a single descriptive statement and in that way arrive at final truth.

There are other ways of arguing this impossibility. The argument of this book – which again, surely, can only convince you insofar as what I say fits with what you know and which may be collapsed or totally changed in a few years – presupposes that science is a *way of perceiving* and making what we may call "sense" of our percepts. But perception operates only upon difference. All receipt of information is necessarily the receipt of news of *difference,* and all perception of difference is limited by threshold. Differences that are too slight or too slowly presented are not perceivable. They are not food for perception.

It follows that what we, as scientists, can perceive is always limited by threshold. That is, what is subliminal will not be grist for our mill. Knowledge at any given moment will be a function of the thresholds of our available means of perception. The invention of the microscope or the telescope or of means of measuring time to the faction of a nanosecond or weighing quantities of matter to millionths of a gram – all such improved devices of perception will disclose what was utterly unpredictable from the levels of perception that we could achieve before that discovery.

Not only can we not predict into the next instant of future, but, more profoundly, we cannot predict into the next dimension of the microscopic, the astronomically distant, or the geologically ancient. As a method of perception – and that is all science can claim to be – science, like all other methods of perception, is limited in its ability to collect the outward and visible signs of whatever may be truth.

Science *probes*; it does not prove.

2. THE MAP IS NOT THE TERRITORY, AND THE NAME IS NOT THE THING NAMED

This principle, made famous by Alfred Korzybski, strikes at many levels. It reminds us in a general way that when we think of coconuts or pigs, there are no coconuts or pigs in the brain. But in a more abstract way, Korzybski's statement asserts that in all thought or perception or communication about perception, there is a transformation, a coding, between the report and the thing reported, the *Ding an sich*. Above all, the relation between the report and that mysterious thing reported tends to have the nature of a classification, an assignment of the thing to a class. Naming is always classifying, and mapping is essentially the same as naming.

Korzybski was, on the whole, speaking as a philosopher, attempting to persuade people to discipline their manner of thinking. But he could not win. When we come to apply his dictum to the natural history of human mental process, the matter is not quite so simple. The distinction between the name and the thing named or the map and the territory is perhaps really made only by the dominant hemisphere of the brain. The symbolic and affective hemisphere, normally on the right-hand side, is probably unable to distinguish name from thing named. It is certainly not concerned with this sort of distinction. It therefore happens that certain nonrational types of behavior are necessarily present in human life. We do, in fact, have two hemispheres; and we cannot operate somewhat differently from the other, and we cannot get away from the tangles that that difference proposes.

For example, with the dominant hemisphere, we can regard such a thing as a flag as a sort of name of the country or organization that it represents. But the right hemisphere does not draw this distinction and regards the flag as sacramentally identical with what it represents. So "Old Glory" is the United States. If somebody steps on it, the response may be rage. And this rage will not be diminished by an explanation of map-territory relations. (After all, the man who tramples the flag is equally identify it with that for which it stands.) There is always and necessarily be a large number of situations in which the response is not guided by the logical distinction between the name and the thing named.

3. THERE IS NO OBJECTIVE EXPERIENCE

All experience is subjective. This is only a simple corollary of a point made in section 4: that our brains make the images that we think we "perceive."

It is significant that all perception – all conscious perception – has image characteristics. A pain is localize somewhere. It has a beginning and an end and a location and stands out against a background. These are the elementary components of an image. When somebody steps on my toe, what I experience is, not his stepping on my toe, but my *image* of his stepping on my toe reconstructed from neural reports reaching my brain somewhat after his foot has landed on mine. Experience of the exterior is always mediated by particular sense organs and neural pathways. To that extent, objects are creation, and my experience of them is subjective, not objective.

It is, however, not a trivial assertion to note that very few persons, at least in occidental culture, doubt the objectivity of such sense data as pain or their visual images of the external world. Or civilization is deeply based on this illusion.

4. THE PROCESSES OF IMAGE FORMATION ARE UNCONSCIOUS

This generalization seems to be true of everything that happens between my sometimes conscious action of directing a sense organ at some source of information and my conscious action of deriving information from an image that "I" seem to see, hear, feel, taste, or smell. Even a pain is surely a created image.

No doubt men and donkeys and dogs are conscious of listening and even of cocking their ears in the direction of sound. As for sight, something moving the periphery of my visual field will call "attention" (whatever that means) so that I shift my eyes and even my head to look at it. This is often a conscious act, but it is sometimes so nearly automatic that it goes unnoticed. Often I am conscious of turning my head but unaware of the peripheral sighting that caused me to turn. The peripheral retina receives a lot of information that remains outside consciousness – possibly but not certainly in image form.

The *processes* of perception are inaccessible; only the products are conscious and, of course, it is the products that are necessary. The two general facts – first, that I am unconscious of the process of making the images which I consciously see and, second, that in these unconscious processes, I use a whole range of presuppositions which become built into the finished image – are, for me, the beginning of empirical epistemology.

Of course, we all know that the images which we "see" are indeed manufactured by the brain or mind. But to know this in an intellectual sense is very different from realizing that it is truly so. This aspect of the matter came forcibly to my attention some thirty years ago in New York, where Adalbert Ames, Jr., was demonstrating his experiments on how we endow our visual images with depth. Ames was an ophthalmologist who had worked with patients who suffered from anisoconia; that is, they formed images of different sizes in the two eyes. This led him to study the subjective components of the perception of depth. Because this matter is important and provides the very basis of empirical or experimental epistemology, I will narrate my encounter with the Ames experiments in some detail.

Ames had the experiments set up in a large, empty apartment in New York City. There were, as I recall, some fifty experiments. When I arrived to see the show, I was the only visitor. Ames greeted me and suggested that I start at the beginning of the sequence of demonstrations while he went back to work for awhile in a small room furnished as an office. Otherwise, the apartment contained no furniture except for two folding deck chairs.

I went from one experiment to the next. Each contained some sort of optical illusion affecting the perception of depth. The thesis of the whole series was that we use five main clues to guide us in creating the appearance of depth in the images that we cerate as we look out through our eyes at the world.

The first of these clues is size; * that is, the size of the physical image on the retina. Of course, we cannot *see* this image so it would be more exact to say the first clue to distance is the angle which the object subtends at the eye. But indeed this angle is also not visible. The clue to distance which is reported on the optic nerve is perhaps *change in angle subtended*. [*1] The demonstration of this truth was a pair of balloons in a dark area. The balloons themselves were equally illuminated, but their air could be passed from one balloon into the other. The balloons themselves did not move, but as one grew and the other shrank, it appeared to the observer that the one which grew, approached, and the one which shrank, retreated. As the air was shifted form one balloon to the other and back again, the balloons appeared to move alternately forward and back.

The second clue was contrast in brightness. To demonstrate this, the balloons stayed the same size and, of course, did not really move. Only the illumination changed, shining first on one balloon and then on the other. This alternation of illumination, like the alternation in size, gave the balloons the appearance of approaching and retreating in turn as the light fell first on one and then on the other.

Then the sequence of experiments showed that these two clues, size and brightness, could be played against each other to give a contradiction. The shrinking now always got more light. This combined experiment introduced the idea that some clues are dominant over others.

The total sequence of clues demonstrated that day included size, brightness, overlap, binocular parallax, and parallax created by movements of the head. Of these, the most strongly dominant was parallax by head motion.

After looking at twenty or thirty such demonstrations, I was ready to take a break and went to sit in one of the folding deck chairs. It collapsed under me. Hearing the noise, Ames came out to check that all was well. He then stayed with me and demonstrated the two following experiments.

The first dealt with parallax (see Glossary). On a table perhaps five feet long, there were two objects: a pack of Lucky Strike cigarettes, supported on a slender spike some inches from the surface of the table and a book of paper matches, similarly raised on a spike, at the far end of the table.

Ames had me stand at the near end of the table and describe what I saw; that is, the location of the two objects and how big they seemed to be. (In Ames's experiments, you are always made to observe the truth before being subjected to the illusions.)

Ames then pointed out to me that there was a wooden plank with a plain round hole in it set upright at the edge of the table at my end so that I could look through the hole down the length of the table. He had me look through this hole and tell him what I saw. Of course, the two objects still appeared to be where I know them to be and to be of their familiar sizes.

Looking through the hole in the plank, I had lost the crow's-eye view of the table and was reduced to the use of a single eye. But Ames suggested that I could get parallax on the objects by sliding the plank sideways.

As I moved my eye sideways with the plank, the image changed totally – as if by magic. The Lucky Strike pack was suddenly at the far end of the table and appeared to be about twice as tall and twice as wide as a normal pack of cigarettes. Even the surface of the paper of which the pack was made had changed in texture. Its small irregularities were now seemingly larger. The book of matches, on the other hand, suddenly appeared to be of dollhouse size and to be located halfway down the length of the table in the position where the pack of cigarettes had formerly been seen to be.

What had happened?

The answer was simple. Under the table, where I could not see them, there were two levers or rods that moved the two objects sideways as I move the plank. In normal parallax, as we all know, when we look out from a moving train, the objects close to us appear to be left behind fast; the cows beside the railroad track do not stay to be observed. The distant mountains, on the other hand, are left behind so slowly that, in contrast with the cows, they seem almost to travel with the train.

In this case, the levers under the table caused the nearer object to move along with the observer. The cigarette pack was made to act as if it were far away; the book of matches was made to move as if it were close by.

In other words, by moving my eye and with it the plank, I created a reversed appearance. Under such circumstances, the unconscious processes of image formation made the appropriate image. The information from the cigarette pack was read and built up to be the image of a distant pack, but the height of the pack still subtended the same angle at the eye. Therefore, the pack now appeared to be of giant size. The book of matches, correspondingly, was brought seemingly close but still subtended the same angle that it subtended from its true location. What I created was an image in which the book of matches appeared to be half as far away and half its familiar size.

The machinery of perception created the image in accordance with the rules of parallax, rules that were for the first time clearly verbalized by painters in the Renaissance; and this whole process, the creating of the image with its built-in conclusion from the clues of parallax, happened quite outside my consciousness. The rules of the universe that we think we know are deep buried in our processes of perception.

Epistemology, at the natural history level, is mostly unconscious and correspondingly difficult to change. The second experiment that Ames demonstrated illustrates this difficulty of change.

This experiment has been called the *trapezoidal room*. In this case, Ames had me inspect a large box about five feet long, three feet high, and three feet deep from front to back. The box was of strange trapezoidal shape, and Ames asked me to examine it carefully in order to learn its true shape and dimensions.

In the front of the box was a peephole big enough for two eyes, but before beginning the experiment, Ames had me put on a pair of prismatic spectacles that would corrupt my binocular vision. I was to have the subjective presupposition that I had the parallax of two eyes when indeed I had almost no binocular clues.

When I looked in through the peephole, the interior of the box appeared to be quite rectangular and was marked out like a room with rectangular windows. The true lines of paint suggesting windows were, of course, far from simple; they were drawn to give the impression of rectangularity, contradicting the true trapezoidal shape of the room. The side of the box toward which I faced when looking through the peephole was, I know from my earlier inspection, obliquely placed, so that it was further from me at the left end and closer to me on the right.

Ames gave me a stick and asked me to reach in and touch with the point of the stick a sheet of type-writing paper pinned to the left-hand wall. I managed this fairly easily. Ames then said. "Do you see a similar piece of paper on the right-hand side? I want you to hit that second piece of paper with the stick. Start with the end of your stick against the left-hand paper, and hit as hard as you can."

I smote hard. The end of my stick moved about an inch and then hit the back of the room and could move no father. Ames said, "Try again."

I tried perhaps fifty times, and my arm began to ache. I know, of course, what correction I had to impose on my movement: I had to pull in as I struck in order to avoid that back wall. But what I did was governed by my image. I was trying to pull against my own spontaneous movement (I suppose that if I had shut my eyes, I could have done better, but I did not try that.)

I never did succeed in hitting the second piece of paper, but, interestingly, my performance improved. I was finally able to move my stick several inches before it hit the back wall. And *as I practised and improved my action*, my image changed to give me a more trapezoidal impression of the room's shape.

Ames told me afterward that, indeed, with more practice, people learned to hit the second paper very easily and, at the same time, learned to see the room in its true trapezoidal shape.

The trapezoidal room was the last in the sequence of the experiments, and after it, Ames suggested that we go to lunch. I went to wash up in the bathroom of the apartment. I turned the faucet marked "C" and got a jet of boiling water mixed with steam.

Ames and I then went down to find a restaurant. My faith in my own image formation was so shaken that I could scarcely cross the street. I was not sure that the oncoming cars were really where they seemed to be from moment to moment.

In sum, there is no free will against the immediate commands of the images that perception presents to the "mind's eye." But through arduous practice and self-correction, it is partly possible to alter those images. (Such changes in calibration are further discussed in Chapter 7.)

In spite of this beautiful experimentation, the fact of image formation remains almost totally mysterious.

How it is done, we know not – nor, indeed, for what purpose.

It is all very well to say that it makes a sort of adaptive sense to present only the images to consciousness without wasting psychological process on consciousness of their making. But there is no clear primary reason for using images at all or, indeed, for being *aware* of any part of our mental processes.

Speculation suggests that image formation is perhaps a convenient or economical method of passing information across some sort of *interface*. Notably, where a person must act in a context between two machines, it is convenient to have the machines feed their information to him or her in image form.

A case that has been studied systematically is that of a gunner controlling antiaircraft fire on a naval ship. [*2] The information from a series of sighting devices aimed at a flying target is summarized for the gunner in the form of a moving dot on a screen (i.e., an image). On the same screen is a second dot, whose position summarizes the direction in which an antiaircraft gun is aimed. The man can moved this second dot by turning knobs on the device. These knobs also change the gun's aim. The man must operate the knobs until the dots coincide on the screen. He then fires the gun.

The system contains tow interfaces: sensory system-man and man-effector system. Of course, it is conceivable that in such a case, both the input information and the output information could be processed in digital form, without transformation into an iconic mode. But it seems to me that the iconic device is surely more convenient not only because, being human, I an a maker of mental images but also because at these interfaces images are economical or efficient. If that speculation is correct, then it would be reasonable to guess that mammals form images because the mental processes of mammals must deal with many interfaces.

There are some interesting side effects of our unawareness of the processes of perception. For example, when these processes work unchecked by input material from a sense organ, as in dream or hallucination or eidetic (see Glossary) imagery, it is sometimes difficult to doubt the external reality of what the images seem to represent. Conversely, it is perhaps a very good thing that we do not know too much about the work of creating perceptual images. In our ignorance of that work, we are free to believe what our senses tell us. To doubt continually the evidence of sensory report might be awkward.

5. THE DIVISION OF THE PERCEIVED UNIVERSE INTO PORTS AND WHOLE IS CONVENIENT AND MAY BE NECESSARY,[*3] BUT NO NECESSITY DETERMINES HOW IT SHALL BE DONE

I have tried many times to reach this generality to classes of students and for this purpose have used Figure 1. The figure is presented to the class as a reasonably accurate chalk drawing on the blackboard, but without the letters marking the various angles. The class is asked to describe "it" in a page of written English. When each student has finished his or her description, we compare the results. They fall into several categories:

a. About 10 percent or less of students say, for example, that the object is a boot or more picturesquely, the boot of a man with a gouty toe or even a toilet.

Figure 1

Figure 1

Evidently, from this and similar analogic or iconic descriptions, it would be difficult for the hearer of the description to reproduce the object.

b. A much larger number of students see the object contains most of a rectangle and most of a hexagon, and having divided it into parts in this way, then devote themselves to trying to describe the relations between the incomplete rectangle and hexagon. A small number of these (but, surprisingly, usually one or two in every class) discover that a line, *BH*, can be drawn and extended to cut the base line, *DC*, at a point *I* in such a way that *HI* will complete a regular hexagon (Figure 2). This imaginary line will define the proportions of the rectangle but not, of course, the absolute lengths. I usually congratulate these students on their ability to create what resembles many scientific hypotheses, which "explain" a perceptible regularity in terms of some entity created by the imagination.
c. Many well-trained students resort to an operational method of description. They will start from some point on the outline of the object (interestingly enough, always an angle) and proceed from there, usually clockwise, with instructions for drawing the object.
d. There are also two other well-known ways of description that no students has yet followed.

Figure 2

Figure 2

> No student has started from the statement "It's made of chalk and blackboard." No student has ever used the method of the halftone block, dividing the surface of the blackboard into grid (arbitrarily rectangular) and reporting "yes" and "no" on whether each box of the grid contains or does not contain some part of the object. Of course, if the grid is coarse and the object small, a very large amount of information will be lost. (Imagine the case in which the entire object is smaller than the grid unit. The description will then consist of not more than four or less than one affirmation, according to how the divisions of the grid fall upon the object.) However, this is, in principle, how the halftone blocks of newspaper illustration are transmitted by electric impulse and, indeed, how television works.

Note that all these methods of description contribute nothing to an *explanation* of the object-the hexago-rectangle. Explanation must always grow out of description, but the description from which it grows will always necessarily contain arbitrary characteristics such as those exemplified here.

6. DIVERGENT SEQUENCES ARE UNPREDICTABLE

According to the popular image of science, everything is, in principle, predictable and controllable; and if some event or process is not predictable and controllable in the present state of your knowledge, a little more knowledge and, especially, a little more know-how will enable us to predict and control the wild variables.

This view is wrong, not merely in detail, but in principle. It is even possible to define large classes or phenomena where prediction and control are simply impossible for very basic but quite understandable reasons. Perhaps the most familiar example of this class of phenomena is the breaking of any superficially homogeneous material, such as glass. The Brownian movement (see Glossary) of molecules in liquids and gases is similarly unpredictable.

If I throw a stone at a glass window, I shall, under appropriate circumstances, break of crack the glass in a star-shaped pattern. If my stone hits the glass as fast as a bullet, it is possible that it will detach from the glass a neat conical plug called a *conic of percussion.* If my stone is too slow and too small, I may fail to break the glass at all. Prediction and control will be quite possible at this level. I can easily make sure which of three results (the star, the percussion cone, or no breakage) I shall achieve, provided I avoid marginal strengths of throw.

But within the conditions which produce the star-shaped break, it will be impossible to predict or control the pathways and the positions of the arms of the stars.

Curiously enough, the more precise my laboratory methods, the more unpredictable the events will become. If I use the most homogeneous glass available, polish its surface to the most exact optical flatness, and control the motion of my stone as precisely as possible, ensuring an almost precisely vertical impact on the surface of the glass, all my efforts will only make the events more impossible to predict.

If, on the other hand, I scratch the surface of the glass or use a piece of glass that is already cracked (which would be cheating), I shall be able to make some approximate predictions. For some reason (unknown to me), the break in the glass will run parallel to the scratch and about 1/100 of an inch to the side, so that the scratch mark will appear on only one side of the break. Beyond the end of the scratch, the break will veer off unpredictably.

Under tension, a chain will break at its weakest link. That much is predictable. What is difficult is to identify the weakest link before it breaks. *The generic we can know, but the specific eludes us.* Some chains are designed to break at a certain tension and at a certain link. But a good chain is homogeneous, and no prediction is possible. And because we cannot know which link is weakest, we cannot know precisely how much tension will be needed to break the chain.

If we heat a clear liquid (say, clean distilled water) in a clean, smooth beaker, at what point will the first bubble of steam appear? At what temperature? And at what instant?

These questions are unanswerable unless there is a tiny roughness in the inner surface of the beaker or a speck of dust in the liquid. In the absence of such an evident nucleus for the beginning of the change of state, no prediction is possible; and because we cannot say where the change will start, we also cannot say *when.* Therefore, we cannot say at what temperature boiling will begin.

If the experiment is critically performed – that is, if the water is very clean and the beaker very smooth – there will be some superheating. In the end, the water will boil. In the end, there will always be a *difference* that can serve as the nucleus for the change. In the end, the superheated liquid will "find" this differentiated spot and will boil explosively for a few moments until the temperature is reduced to the regular boiling point appropriate to the surrounding barometric pressure.

The freezing of liquid is similar, as is the falling out of crystals from a supersaturated solution. A nucleus – that is, a differentiated point, which in the case of a supersaturated solution may, indeed, be a microscopic crystal – is needed for the process to start.

We shall note elsewhere in this book that there is a deep gulf between statements about an identified individual and statements about a class. Such statements are of *different logical type*, and prediction form one to the other is always unsure. The statement "The liquid is boiling" is of different logical type from the statement "That molecule will be the first to go."

The matter has a number of sorts of relevance to the theory of history, to the philosophy behind evolutionary theory, and in general, to our understanding of the world in which we live.

In the theory of history, Marxian philosophy, following Tolstoi, insists that the great men who have been the historic nuclei for profound social change or invention are, in a certain sense, irrelevant to the changes they precipitated. It is argued, for example, that in 1859, the occidental world was ready and ripe (perhaps overripe) to create and receive a theory of evolution that could reflect and justify the ethics of the Industrial Revolution. From that point of view, Charles Darwin himself could be made to appear unimportant. If he had not put out his theory, somebody else would have put out a similar theory within the next five years. Indeed, the parallelism between Alfred Russel Wallace's theory and that of Darwin would seam at first sight to support this view.[*4]

The Marxians would, as I understand it, argue that there is bound to be a weakest link, that under appropriate social forces [*5] or tensions, some individual will be the first to start the trend, and that it does not matter who.

But, of course, it *does* matter who starts the trend. If it had been Wallace instead of Darwin, we would have a very different theory of evolution today. The whole cybernetics movement might have occurred 100 years earlier as a result of Wallace's comparison between the steam engine with a governor and the process of natural selection. Or perhaps the big theoretical step might have occurred in France and evolved from the ideas of Claude Bernard who in the late nineteenth century, discovered what later came to be called the *homeostasis* of the body. He observed that the *milieu interne* – the internal environment – was balanced or self-correcting.

It is, I claim, nonsense to say that it does not matter which individual man acted as the nucleus for the change. It *is precisely this that makes history unpredictable into the future*. The Marxian error is a simple blunder in logical typing, a confusion of individual with class.

7. CONVERGENT SEQUENCES ARE PREDICTABLE

This generality is the converse of the generality examined in section 6, and the relation between the two depends on the contrast between the concepts of divergence and convergence. This contrast is a special case, although a very fundamental one, of the difference between successive levels in a Russellian hierarchy, a matter to be discussed in Chapter 4. For the moment, it should be noted that the components of a Russellian hierarchy are to each other as member to class, as class to class of classes, or as thing named to name.

What is important about divergent sequences is that our description of them concerns *individuals*, especially individual molecules. The crack in the glass, the first step in the beginning of the boiling of water, and all the rest are cases in which the location and instant of the event is determined by some momentary constellation of a small number of individual molecules. Similarly, any description of the pathways of individual molecules in Brownian movement allows no extrapolation. What happens at one moment, even if we could know it, would not give us data to predict that will happen at the next.

In contrast, the movement of planets in the solar system, the trend of a chemical reaction in an ionic mixture of salts, the impact of billiard balls, which involves millions of molecules – all are predictable because our description of the events has as its subject matter the behavior of immense crowds or classes of individuals. It is this that gives science some justification for statistics, providing the statistician always remembers that his statements have reference only to aggregates.

In this sense, the so-called laws of probability mediate between descriptions of that of the gross crowd. We shall see later that this particular sort of conflict between the individual and the statistical has dogged the development of evolutionary theory from the time of Lamarck onward. If Lamarck had asserted that changes in environment would affect the general characteristics of whole populations, he would have been in step with the latest genetic assimilation, to be discussed in Chapter 6. But Lamarck and, indeed, his followers ever since have seemed to have an innate proclivity for confusion of logical types. (This matter and the corresponding confusions of orthodox evolutionists will be discussed in Chapter 6.)

Be all that as it may, in the stochastic processes (see Glossary) either of evolution or of thought, the new can be plucked from nowhere but the random. And to pluck the new from the random, if and when it happens to show itself, requires some sort of selective machinery to account for the ongoing persistence of the new idea. Something like *natural selection*, in all its truism and tautology, must obtain. To persist, the new must be of such a sort that it will endure longer than the alternatives. What lasts longer among the ripples of the random must last longer than those ripples that last not so long. That is the theory of natural selection in a nutshell.

The Marxian view of history – which in its crudest form would argue that if Darwin had not written *The Origin of Species,* somebody else would have produced a similar book within the next five years – is an unfortunate effort to apply a theory that would view social process as *convergent* to events involving unique human beings. The error is, again, of logical typing.

8. "NOTHING WILL COME OF NOTHING"

This quotation of *King Lear* telescopes into a single utterance a whole series of medieval and more modern wise saws. These include:

a. The law of the conversation of matter and its converse, that no new matter can be expected to make an appearance in the new laboratory. (Lucretius said "Nothing can ever be created out of nothing by divine power." *6)
b. The law of the conservation of energy and its converse, that no new energy can be expected in the laboratory.
c. The principle demonstrated by Pasteur, that no new living matter can be expected to appear in the laboratory.
d. The principle that no new order or pattern can be created without *information.*

Of all these and other similar negative statements, it may be said that they are rules for expectation rather than laws of nature. They are so nearly true that all exceptions are of extreme interest.

What is especially interesting is hidden in the relations between these profound negations. For example, we know today that between the conservation of energy and the conservation of matter, there is a bridge whereby each of these negations is itself negated by an interchange of matter into energy and, presumably, of energy into matter.

In the present connection, however, it is the last of the series that is of chief interest, the proposition that in the realms of communication, organization, thought, learning, and evolution, "nothing will come of nothing" without *information.*

This law differs from the conservative laws of energy and mass in that it contains no clause to deny the destruction and loss of information, pattern, or negative entropy. Alas - but also be glad of it - pattern, and/or information is all too easily eaten up by the random. The messages and guidelines for order exist only, as it were, in sand or are written on the surface of waters. Almost any disturbance, even mere Brownian movement, will destroy them. Information can be forgotten or blurred. The code books can be lost.

The messages cease to be messages when nobody can read them. Without a Rosetta stone, we would know nothing of all that was written in Egyptian hieroglyphs. They would be only elegant ornaments on papyrus or rock. To be meaningful - even to be recognized as pattern - every regularity must meet with complementary regularities, perhaps skills, and these skills are as evanescent as the patterns themselves. They, too, are written on sand or the surface of waters.

The genesis of the skill to respond to the message is the obverse, the other side of the process of evolution. It is *coevolution* (see Glossary).

Paradoxically, the deep partial truth that "nothing will come of nothing" in the world of information and organization encounters an interesting contradiction in the circumstance that *zero*, the complete absence of any indicative event, can be a message. The larval tick climbs a tree and waits on some outer twig. If he smells sweat, he falls, perhaps landing on a mammal. But if he smells *no sweat* after some weeks, he falls and goes to climb another tree.

The letter that you do not write, the apology you do not offer, the food that you do not put out for the cat - all these can be sufficient and effective messages because zero, *in context*, can be meaningful; and it is the recipient of the message who creates the context. This power to create *context* is the recipient's skill; to acquire which is his half of the coevolution mentioned above. He or she must acquire that skill by learning or by lucky mutation, that is, by a successful raid on the random. The recipient must be, in some sense, ready for the appropriate discovery when it comes.

Thus, the converse of the proposition that "nothing will come of nothing" without information is conceivably possible with stochastic process. *Readiness* can serve to select components of the random which thereby become new information. But always a supply of random appearances must be available from which new information can be made.

This circumstance splits the entire field of organization, evolution, maturation and learning, into two separate realms, of which one is the realm of epigenesis, or embryology, and the other the realm of evolution and learning.

Epigenesis is the word preferred by C.H. Waddington for his central field of interest, whose old name was *embryology*. It stresses the fact that every embryological step is an act of *becoming* (Greek *genesis*) which must be built *upon* (Greek *epi*) the immediate status quo ante. Characteristically, Waddinton was contemptuous of conventional information theory, which allowed nothing, as he saw it, for the "new" information he felt was generated at each stage of epigenesis. Indeed, according to conventional theory, there is no new information in this case.

Ideally, epigenesis should resemble the development of a complex tautology (see Glossary) in which nothing is added after the axioms and definitions have been laid down. The Pythagorean theorem is implicit (i.e., already folded into) Euclid's axioms, definitions, and postulates. All that is required is its unfolding and, for human beings, some knowledge of the order of steps to be taken. This latter species of information will become necessary only when Euclid's tautology is modeled in words and symbols sequentially arranged on paper or in time. In the ideal tautology, there is no time, no unfolding, and no argument. What is implicit is there, but, of course, not located in space.

In contrast with epigenesis and tautology, which constitute the worlds of replication, there is the whole realm of creativity, art, learning, and evolution, in which the ongoing processes of change *feed on the random*. The essence of epigenesis is predictable repetition; the essence of learning and evolution is exploration and change.

In the transmission of human culture, people always attempt to replicate, to pass on to the next generation the skills and values of the parents; but the attempt always and inevitably fails because cultural transmission is geared to learning, not to DNA. The process of transmission of culture is a sort of hybrid or mix-up of the two realms. It must attempt to use the phenomena of learning of the purpose of replication because what the parents have was learned by them. If the offspring miraculously had the DNA that would give them the parental skills, those skills would be *different* and perhaps nonviable.

It is interesting that between the two worlds is the cultural phenomenon of explanation -- the mapping onto [*7] tautology of unfamiliar sequences of events.

Finally, it will be noted that the realms of epigenesis and of evolution are, at a deeper level, typified in the twin paradigms of the second law of thermodynamics.
(1) that the random workings of probability will always eat up order, pattern, and negative entropy but
(2) that for the creation of new order, the workings of the random, the plethora of uncommitted alternatives (entropy) is necessary. It is out of the random that organisms collect new mutations, and it is there that stochastic learning gathers its solutions. Evolution leads to climax: ecological saturation of all the possibilities of differentiation. Learning leads to the overpacked mind. By return to the unlearned and mass-produced egg, the ongoing species again and again clears its memory banks to be ready for the new.

9. NUMBER IS DIFFERENT FROM QUANTITY

This difference is basic for any sort of theorizing behavioral science, for any sort of imagining of what goes on between organisms or inside organisms as part of their processes of thought.

Numbers are the product of counting. *Quantities* are the product of measurement. This means that numbers can conceivably be accurate because there is a discontinuity between each integer and the next. Between two and three, there is a jump. In the case of quantity, there is no such jump; and because jump is missing in the world of quantity, it is impossible for any quantity to be exact. You can have exactly three tomatoes. You can never have exactly three gallons of water. Always quantity is approximate.

Even when number and quantity are clearly discriminated, there is another concept that must be recognized and distinguished from both number and quantity. For this other concept, there is, I think, no English word, so we have to be content with remembering that there is a subset of patterns whose members are commonly called "numbers." Not all numbers are the products of counting. Indeed, it is the smaller, and therefore commoner, numbers that are often not counted but recognized as patterns at a single glance. Card-players do not stop to count the pips in the eight of spades and can even recognize the characteristic patterning of pips up to "ten."

In other words, number is of the world of pattern, gestalt, and digital computation; quantity is of the world of analogic and probabilistic computation.

Some birds can somehow distinguish number up to seven. But whether this is done by counting or by pattern recognition is not known. The experiment that came closest to testing this difference between the two methods was performed by Otto Koehler with a jackdaw. The bird was trained to the following routine: A number of small cups with lids are set out. In these cups, small pieces of meat are placed. Some cups have one piece of meat, some have two or three, and some cups have none. Separate from the cups, there is a plate on which there is a number of pieces of meat greater that the total number of pieces in the cups. The jackdaw learns to open each cup. Taking off the lid, and then eats any pieces of meat that are in the cup. Finally, when he has eaten all the meat in the cups, he may go to the plate and there eat the same number of pieces of meat that he got form the cups. The bird is punished if he eats more meat from the plate than was in the cups. This routine he is able to learn.

Now, the question is: is the jackdaw counting the pieces of meat, or is he using some alternative method of identifying the number of pieces? The experiment has been carefully designed to push the bird toward counting. His actions are interrupted by his having to lift the lids, and the sequence has been further confused by having some cups contain more than one piece of meat and some contain none. By these devices, the experimenter has tried to make it impossible for the jackdaw to create some sort of pattern or rhythm by which to recognize the number of pieces of meat. The bird is thus forced, so far as the experimenter could force the matter, to count the pieces of meat.

It is still conceivable, of course, that the taking of the meat from the cups becomes some sort of rhythmic dance and that this rhythm is in some way repeated when the bird takes the meat from the plate. The matter is still conceivably in doubt, but on the whole, the experiment is rather convincing in favor of the hypothesis that the jackdaw is counting the pieces of meat rather than recognizing a pattern either of pieces or of his own actions.

It is interesting to look at the biological world in terms of this question: Should the various instances in which number is exhibited by regarded as instances of gestalt, of counted number, or of mere quantity? There is a rather conspicuous difference between, for example, the statement "This single rose has five petals, and it has five sepals, and indeed its symmetry is of a pentad pattern" and the statement "This rose has one hundred and twelve stamens, and that other has ninety-seven, and this has only sixty-four." The process which controls the number of stamens is surely different from the process that controls the number of petals or sepals. And, interestingly, in the double rose, what seems to have happened is that some of the stamens have been converted into petals, so that the process for determining how many petals to make has now become, not the normal process delimiting petals to a pattern of five, but more like the process determining the *quantity* of stamens. We may say that petals are normally "five" in the single rose but that stamens are "many" where "many" is a quantity that will vary from one rose to another.

With this difference in mind, we can look at the biological world and ask what is the largest number that the processes of growth can handle as a fixed pattern, beyond which the matter is handled as quantity. So far as I know, the "numbers" two, three, four, and five are the common ones in symmetry of plants and animals, particularly in radial symmetry.

The reader may find pleasure in collecting cases of rigidly controlled or patterned numbers in nature. For some reason, the larger numbers seem to be confined to linear series of segments, such as the vertebrae of mammals, the abdominal segments of insects, and the anterior segmentation of earthworms. (At the front end, the segmentation is rather rigidly controlled down to the segments bearing genital organs. The numbers vary with the species but may reach fifteen. After that, the tail has "many" segments.) An interesting addition to these observations is the common circumstance that an organism, having chosen a number for the radial symmetry of some set of parts, will repeat that number in other parts. A lily has three sepals and then three petals and then six stamens and a trilocular ovary.

It appears that what seemed to be a quirk or peculiarity of human operation - namely, that we occidental humans get numbers by counting or pattern recognition while we get quantities by measurement - turns out to be some sort of universal truth. Not only the jackdaw but also the rose are constrained to show that for them, too - for the rose in its anatomy and for the jackdaw in its behavior (and, of course, in its vertebral segmentation) - there is this profound difference between numbers and quantity.

What does this mean? That question is very ancient and certainly goes back to Pythagoras, who is said to have encountered a similar regularity in the relation between harmonics.

The hexago-rectangle discussed in section 5 provides a means of posing these questions. We saw, in that case, that the components of description could be quite various. In that particular case, to attach more validity to one rather than to another *way of organizing* the description would be to indulge illusion. But in this matter of biological numbers and quantities, it seems that we encounter something more profound. Does this case differ from that of the hexago-rectangle? And if so, how?

I suggest that neither case is as trivial as the problems of the hexago-rectangle seemed to be at first sight. We go back to the eternal verities of Saint Augustine: "Listen to the thunder of that saint, in about A.D. 500: 7 and 3 are 10; 7 and 3 have always been 10; 7 and 3 at no time and in no way have ever been anything but 10; 7 and 3 will always be 10." [*8]

No doubt, in asserting the contrast between numbers and quantities, I am close to asserting an eternal verity, and Augustine would surely agree.

But we can replay to the saint, "Yes, very true. But is that really what you want and mean to say? It is also true, surely, that 3 and 7 are 10, and that 2 and 1 and 7 are 10, and that 1 and 1 and 1 and 1 and 1 and 1 and 1 and 1 and 1 and 1 are 10. In fact, the eternal verity that you are trying to assert is much more general and profound than the special case used by you to carry that profound message." But we can agree that the more abstract eternal verity will be difficult to state with unambiguous precision.

In other words, it is possible that many of the ways of describing my hexago-rectangle could be only different surfacings of the same more profound and more general tautology (where Euclidean geometry is viewed as a tautological system).

It is, I think, correct to say, not only that the various phrasings of the description of the hexago-rectangle ultimately agree about what the describers thought they saw but also that there is an agreement about a single more general and profound tautology in terms of which the various descriptions are organized.

In this sense, the distinction between numbers and quantities is, I believe, nontrivial and is shown to be so by the anatomy of the rose with its "5" petals and its "many" stamens, and I have put quotation marks into my description of the rose to suggest that the names of the numbers and of the quantities are the surfacing of formal ideas, immanent within the growing rose.

10. QUANTITY DOES NOT DETERMINE PATTERN

It is impossible, in principle, to explain any pattern by invoking a single quantity. But note that *a ratio between two quantities* is already the beginning of pattern. In other words, quantity and pattern are of different logical type [*9] and do not readily fit together in the same thinking.

What appears to be a genesis of pattern by quantity arises where the pattern was latent before the quantity had impact on the system. The familiar case is that of tension which will break a chain at the weakest link. Under change of a quantity, tension, a latent difference is made manifest or, as the photographers would say, developed. The development of a photographic negative is precisely the making manifest of latent differences laid down in the photographic emulsion by previous differential exposure to light.

Imagine an island with two mountains on it. A quantitative change, a rise, in the level of the ocean may convert this single island into two islands. This will happen at the point where the level of the ocean rises higher than the saddle between the two mountains. Again, the qualitative pattern was latent before the quantity had impact on it; and when the pattern changed, the change was sudden and discontinuous.

There is a strong tendency in explanatory prose to invoke quantities of tension, energy, and whatnot to explain the genesis of pattern. I believe that all such explanations are inappropriate or wrong. From the point of view of any agent who imposes a quantitative change, any change of pattern which may occur will be unpredictable or divergent.

11. THERE ARE NO MONOTONE "VALUES" IN BIOLOGY

A monotone value is one that either only increases or only decreases. Its curves has no kinks; that is, its curve never changes from increase to decrease or vice versa. Desired substances, things, patterns, or sequences of experience that are in some sense "good" for the organism - items of diet, conditions of life, temperature, entertainment, sex, and so forth - are never such that more of the something is always better than less of the something. Rather, for all objects and experiences, there is a quantity that has optimum value. Above that quantity, the variable becomes toxic. To fall below that value is to be deprived.

This characteristic of biological value does not hold for money. Money is always transitively valued. More money is supposedly always better than less money. Fore example, $1001 is to be preferred to $1000. But this is not so for biological values. More calcium is not always better than less calcium. There is an optimum quantity of calcium that a given organism may need in its diet. Beyond this, calcium becomes toxic. Similarly, for oxygen that we breathe or food or components of diet and probably all components of relationship, enough is better than a feast. We can even have too much psychotherapy. A relationship with no combat in it is dull, and a relationship with too much combat in it is toxic. What is desirable is a relationship with a certain optimum of conflict. It is even possible that when we consider money, not by itself, but as acting on human beings who own it, we may find that money, too, becomes toxic beyond a certain point. In any case, the philosophy of money, the set of presuppositions by which money is supposedly better and better the more you have of it, is totally antibiological. It seems, nevertheless, that this philosophy can be taught to living things.

12. SOMETIMES SMALL IS BEATIFUL

Perhaps no variable brings the problems of being alive so vividly and clearly before the analyst's eye as does size. The elephant is afflicted with the problems of bigness; the shrew, with those of smallness. But for each, there is an optimum size. The elephant would not be better off if he were much smaller, nor would the shrew be relieved by being much bigger. We may say that each is *addicted* to the size that is.

There are purely physical problems of bigness or smallness, problems that affect the solar system, the bridge, and the wristwatch. But in addition to these, there are problems special to aggregates of living matter, whether these be single creatures or whole cities.

Let us first look at the physical. Problems of mechanical *instability* arise because, for example, the forces of gravity do not follow the same quantitative regularities as those of cohesion. A large clod of earth is easier to break by dropping it on the ground than is a small one. The glacier grows and therefore, partly melting and partly breaking, must begin a changed existence in the form of avalanches, smaller units that must fall off the larger matrix. Conversely, even in the physical universe, the very small may become unstable because the relation between surface area and weight is nonlinear. We break up any material which we wish to dissolve because the smaller pieces have a greater ratio of surface to volume and will therefore give more access to the solvent. The larger lumps will be the last to disappear. And so on.

To carry these thoughts over into the more complex world of living things, a fable may be offered:

THE TALE OF THE POLYPLOID HORSE

> They say the Nobel people are still embarrassed when anybody mentions polyploid horses. Anyhow, Dr. P. U. Posif, the great Erewhonian geneticist, got his prize in the late 1980s for jiggling with the DNA of the common cart horse (*Equus caballus*). It was said that he

made a great contribution to the then new science of transportology. At any rate, he got his prize for *creating* - no other word would be good enough for a piece of applied science so nearly usurping the role of deity - creating, I say, a horse precisely twice the size of the ordinary Clydesdale. It was twice as long, twice as high, and twice as thick. It was a polyploid, with four times the usual number of chromosomes.

P.U. Posif always claimed that there was a time, when this wonderful animal was still a colt, when it was able to stand on its four legs. A wonderful it must have been! But anyhow, by the time the horse was shown to the public and recorded with all the communicational devices of modern civilization, the horse was not doing any standing. In a word, it was *too heavy*. It weighed, of course, eight times as much as a normal Clydesdale.

For a public showing and for the media, Dr. Posif always insisted on turning off the hoses that were continuously necessary to keep the beast at normal mammalian temperature. But we were always afraid that the innermost parts would begin to cook. After all, the poor beast's skin and dermal fat were twice as thick as normal, and it surface area was only four times that of a normal horse, so it didn't cool properly.

Every morning, the horse had to be raised to its feet with the aid of a small crane and hung in a sort of box on wheels, in which it was suspended on springs, adjusted to take half its weigh off its legs.

Dr. Posif used to claim that the animal was outstandingly intelligent. It had, of course, eight times as much brain (by weight) as any other horse, but I could never see that it was concerned with any questions more complex than those which interest other horses. I had very little free time, what with one thing and another - always panting, partly to keep cool and partly to oxygenate its eight-times body. Its windpipe, after all, had only four times the normal area of cross section.

And then there was eating. Somehow it had to eat, every day, eight times the amount that would satisfy a normal horse and had to push all that food down an esophagus only four times the caliber of the normal. The blood vessels, too, were reduced in relative size, and this made circulation more difficult and put extra strain on the heart.

A sad beast.

The fable shows what inevitably happens when two or more variables, whose curves are discrepant, interact. That is what produces the interaction between change and tolerance. For instance, gradual growth in a population, whether of automobiles or of people, has no perceptible effect upon a transportation system until suddenly the threshold of tolerance is passed and the traffic jams. The changing of one variable exposes a critical value of the other.

Of all such cases, the best known today is the behavior of fissionable material in the atom bomb. The uranium occurs in nature and is continually undergoing fission, but no explosion occurs because no chain reaction is established. Each atom, as it breaks, gives off neutrons that, that if they hit another uranium atom, may cause fission, but many neutrons are merely lost. Unless the lump of uranium is of critical size, an average of less than one neutron from each fission will break another atom, and the chain will dwindle. If the lump is made bigger, a larger fraction of the neutrons will hit uranium atoms to cause fission. The process will then achieve positive exponential gain and become an explosion.

In the case of the imaginary horse, length, surface area, and volume (or mass) become discrepant because their curves of increase have mutually nonlinear characteristics. Surface varies as the square of length, volume varies as the cube of length, and surface varies as the 2/3 power of volume.

For the horse (and for all real creatures), the matter becomes more serious because to remain alive, many internal motions must be maintained. There is an internal logistics of blood, food, oxygen, and excretory products and a logistics of information in the form of neural and hormonal messages.

The harbor porpoise, which is about three feet long, with a jacket of blubber about one inch thick and a surface area of about six square feet, has a known heat budget that balances comfortably in Arctic waters. The heat budget of a big whale, which is about ten times the length of the porpoise (i.e. 1,000 times the volume and 100 times the surface), with a blubber jacket nearly twelve inches thick, is totally mysterious. Presumably, they have a superior logistic system moving blood through the dorsal fins and tail flukes, where all cetaceans get rid of heat.

The fact of growth adds another order of complexity to the problems of bigness in living things. Will growth alter the proportions of the organism? These problems of the limitation of growth are met in very different ways by different creatures.

A simple case is that of the palms, which do not adjust their girth to compensate for their height. An oak tree with growing tissue (cambium) between its wood, and its bark grows in length and width throughout its life. But a coconut palm, whose only growing tissue is the apex of the trunk (the so-called millionaire's salad, which can only be got at the price of killing the palm), simply gets taller and taller, with some slow increase of the bole at its base. For this organism, the limitation of height is simply a normal part of its adaptation of a niche. The sheer mechanical instability of excessive height without compensation in girth provides its normal way of death.

Many plants avoid (or solve?) these problems of the limitation of growth by linking their life-span to the calendar or to their own reproductive cycle. Annuals start a new generation each year, and plants like the so-called century plant (yucca) may live many years but, like the salmon, inevitably die when they reproduce. Except for multiple branching within the flowering head, the yucca makes no branches. The branching influorescence itself is its terminal stem; when that has completed its function, the plant dies. Its death is normal to its way of life.

Among some higher animals, growth is controlled. The creature reaches a size or age or stage at which growth simply stops (i.e., is stopped by chemical or other messages within the organization of the creature). The cells, under control, cease to grow and divide. When controls no longer operate (by failure to generate the message or failure to receive it), the result is cancer. Where do such messages originate, what triggers their sending, and in what presumably chemical code are these messages immanent? What controls the nearly perfect external bilateral symmetry of the mammalian body? We have remarkably little knowledge of the message system that controls growth. There must be a whole interlocking system as yet scarcely studied.

13. LOGIC IS A POOR MODEL OF CAUSE AND EFFECT

We use the same words to talk about logical sequences and about sequences of cause and effect. We say "*If* Euclid's definitions and postulates are accepted, *then* two triangles having three sides of the one equal to thee sides of the other are equal each to each." And we say, "*If* the temperature falls below 0°C, *then* the water begins to become ice."

But the *if… then* of logic in the syllogism is very different from the *if …then* of cause and effect.

In a computer, which works by cause and effect, with one transistor, triggering another, the sequences of cause and effect are used to *simulate* logic. Thirty years ago, we sued to ask: Can a computer simulate *all* the processes of logic? The answer was yes, but the question was surely wrong. We should have asked: Can logic simulate all sequences of cause and effect? And the answer would have been no.

When the sequences of cause and effect become circular (or more complex than circular), then the description or mapping of those sequences onto timeless logic becomes self-contradictory. Paradoxes are generated that pure logic cannot tolerate. An ordinary buzzer circuit will serve as an example, a single instance of the apparent paradoxes generated in a million cases of homeostasis throughout biology. The buzzer circuit (see Figure 3) is so rigged that current will pass around the circuit when the armature makes contact with the electrode at *A*. But the passage of current activates the electromagnet that will draw the armature away, breaking the contact at *A*. The current will then cease to pass around the circuit, the electromagnet will become inactive, and the armature will return to make contact at *A* and so repeat the cycle.

figure 3

Figure 3

If we spell out this cycle onto a causal sequence, we get the following:

If contact is made at A, *then the magnet is activated.*
If the magnet is activated, then contact at A *is broken.*
If contact at A *is broken, then the magnet is inactivated.*
If magnet is inactivated, than contact is made.

The sequence is perfectly satisfactory provided it is clearly understood that the *if…then* junctures are casual. But the bad pun that would move the *ifs* and *thens* over into the world of logic will create havoc:

If the contact is made, then the contact is broken.

If P, *then not* P.

The *if…then* of causality contains time, but the *if…then* of logic is timeless. It follows that logic is an incomplete model of causality.

14. CAUSALITY DOES NOT WORK BACKWARD

Logic can often be reversed, but the effect does not precede the cause. This generalization has been a stumbling block for the psychological and biological sciences since the times of Plato and Aristotle. The Greeks were inclined to believe in what were later called *final* causes. They believed that the pattern generated at the end of a sequence of events could be regarded as in some way causal of the pathway followed by that sequence. This led to the whole of teleology, as it was called (*telos* meaning the end or purpose of a sequence).

The problem with confronted biological thinkers was the problem of adaptation. It appeared that a crab had claws in order to hold things. The difficulty was always in arguing backward from the purpose of claws to the causation of the development of claws. For a long time, it was considered heretical in biology to believe that claws were there because they were useful. This belief contained the teleological fallacy, an inversion of causality in time.

Lineal thinking will always generate either the teleological fallacy (that end determines process) or the myth of some supernatural controlling agency.

What is the case is that when causal systems become circular (a matter to be discussed in Chapter 4), a change in any part of the circle can be regarded as cause for change at a later time in any variable anywhere in the circle. It thus appears that a rise in the temperature of the room can be regarded as the cause of the change in the switch of the thermostat and, alternatively, that the action of the thermostat can be regarded as controlling the temperature of the room.

15. LANGUAGE COMMONLY STRESSES ONLY ONE SIDE OF ANY INTERACTION

We commonly speak as though a single "thing" could "have" some characteristic. A stone, we say, is "hard," "small," "heavy," "yellow," "dense," "fragile," "hot," "moving," "stationary," "visible," "edible," "inedible" and so on.

That is how our language is made: "The stone is hard." And so on. And that way of talking is good enough for the marketplace: "That is a new brand." "The potatoes are rotten." "The eggs are fresh." "The container is damaged." "The diamond is flawed." "A pound of apples is enough." And so on.

But this way of talking is not good enough in science or epistemology. To think straight, it is advisable to expect all qualities and attributes, adjectives, and so on to refer to at least *two* sets of interactions in time.

"The stone is hard" means a) that when poked it resisted penetration and b) that certain continual interactions among the molecular *parts* of the stone in some way bond the parts together.

"The stone is stationary" comments on the location of the stone relative to the location of the speaker and other possible moving things. It also comments on matters internal to the stone: its inertia, lack of internal distortion, lack of friction at the surface, and so on.

Language continually asserts by the syntax of subject and predicate that "things" somehow "have" qualities and attributes. A more precise way of talking bout insist that the "things" are produced, are seen as separate from other "things," and are made "real" by their internal relations and by their behavior in relationship with other things and with the speaker.

It is necessary to be quite clear about the universal truth that whatever "things" may be in their pleromatic and thingish world, they can only enter the world of communication and meaning by their names, their qualities and their attributes (i.e., by reports of their internal and external relations and interactions).

16. "*STABILITY*" AND "*CHANGE*" DESCRIBE PARTS OF OUR DESCRIPTIONS

In other parts of this book, the word *stable* and also, necessarily, the word *change* will become very important. It is therefore wise to examine these words now in the introductory phase of our task. What traps do these words contain or conceal?

Stable is commonly used as an adjective applied to a thing. A chemical compound, house, ecosystem, or government is described as stable. If we pursue this matter further, we shall be told that the stable object is unchanging under the impact or stress of some particular external or internal variable or, perhaps, that it resists the passage of time.

If we start to investigate what lies behind this use of *stability*, we shall find a wide range of mechanisms. At the simplest level, we have simple physical hardness or viscosity, qualities descriptive of relations of impact between the stable object and some other. At more complex levels, the whole mass of interlocking processes called life may be involved in keeping our object in a *state of change* that can maintain some necessary constants, such as body temperature, blood circulation, blood sugar or even life itself.

The acrobat on the high wire maintains his stability by continual correction of his imbalance.

These more complex examples suggest that when we use *stability* in talking about living things or self-corrective circuits, we should *follow the example of the entities about which we are talking*. For the acrobat on the high wire, his or her so-called "balance" is important; so, for the mammalian body, is its "temperature". The changing state of these important variables from moment to moment is reported in the communication networks of the body. To follow the example of the entity, we should define "stability" always by reference to the *ongoing truth of some descriptive proposition*. The statement "The acrobat is on the high wire" continues to be true under impact of small breezes and vibrations of the wire. This "stability" is the result of continual changes in descriptions of the acrobat's posture and the position of his or her balancing pole.

It follows that when we talk about living entities, statements about "stability" should always be labeled by reference to some descriptive proposition so that the typing of the word, *stable*, may be clear. We shall see later, especially in Chapter 4, that *every* descriptive proposition is to be characterized according to logical typing of subject, predicate, and context.

Similarly, all statements about change require the same sort of precision. Such profound saws as the French "*plus ça change, plus c'est la même chose*" owe their wiseacre wisdom to a muddling of logical types. What "changes" and what "stays the same" are both of them descriptive propositions, but of different order.

Some comment on the list of presuppositions examined in this chapter is called for. First of all, the list is in no sense complete, and there is no suggestion that such a thing as a complete list of verities or generalities could be prepared. Is it even a characteristic of the world in which we live that such a list should be finite?

In the preparation of this chapter, roughly another dozen candidates for inclusion were dropped, and a number of others were removed from this chapter to become integrated parts of Chapters 3, 4, and 5. However, even with its incompleteness, there are a number of possible exercises that the reader might perform with the list.

First, when we have a list, the natural impulse of the scientist is to start classifying or ordering its members. This I have partly done, breaking the list into four groups in which the members are linked together in various ways. It would be a nontrivial exercise to list the ways in which such verities or presuppositions may be connected. The grouping I have imposed is as follows:

A first cluster includes numbers 1 to 5, which seem to be related aspects of the necessary phenomenon of coding. There, for example, the proposition that "science never proves anything" is rather easily recognized as a synonym for the distinction between map and territory; both follow from the Ames experiments and the generalization of natural history that "there is no objective experience."

It is interesting to note that on the abstract and philosophical side, this group of generalizations has to depend very closely on something like Occam's razor or the rule of parsimony. Without some such ultimate criterion, there is no ultimate way of choosing between one hypothesis and another. The criterion found necessary is of simplicity *versus* complexity. But along with these generalizations stands their connection with neurophysiology, Ames experiments, and the like. One wonders immediately whether the material on perception does not go along with the more philosophical material because the process of perception contains something like an Occam's razor or a criterion of parsimony. The discussion of wholes and parts in number 5 is a spelling out of a common form of transformation that occurs in those processes we call *description*.

Numbers 6, 7 and 8 form a second cluster, dealing with questions of the random and the ordered. The reader will observe that the notion that the new can be plucked only out of the random is in almost total contradiction to the inevitability of entropy. The whole matter of entropy and negentropy (see Glossary) and the contrasts between the set of generalities associated with these words and those associated with energy will be dealt with in Chapter 6 in the discussion of the economics of flexibility. Here it is only necessary to note the interesting formal analogy between the apparent contradiction in this cluster and the discrimination drawn in the third cluster, in which number 9 contrasts number with quantity. The sort of thinking that deals with quantity resembles in many ways the thinking that surrounds the concept of energy; whereas the concept of number is much more closely related to the concepts of pattern and negentropy.

The central mystery of evolution lies, of course, in the contrast between statements of the second law of thermodynamics and the observation that the new can only be plucked from the random. It was this contrast that Darwin partly resolved by his theory of natural selection.

The other two clusters in the list as given are 9 to 12 and 13 to 16. I will leave it to the reader to construct his or her phrasings of how these clusters are internally related and to create other clusters according to his/her own ways of thought.

In Chapter 3 I shall continue to sketch in the background of my thesis with a listing of generalities or presuppositions. I shall, however, come closer to the central problems of thought and evolution, trying to give answers to the question: *In what ways can two or more items of information or command work together or in opposition?* This question with its multiple answers seems to me to be central to any theory of thought or evolution.

* More precisely, I should have written: "The first of these clues is *contrast* in size…" [Back to text]

*1 I observe not only that the processes of visual perception are inaccessible to consciousness but also that it is impossible to construct in words any acceptable description of what must happen in the simplest act of seeing. For that which is not conscious, the language provides no means of expression. [Back to text]

*2 John Stroud, personal communication. [Back to text]

*3 The question of formal necessity raised here might have an answer as follows: Evidently, the universe is characterized by an uneven distribution of causal and other types of linkage between its parts; that is, there are regions of dense linkage separated from each other by regions of less dense linkage. It may be that there are necessarily and inevitably processes which are responsive to the density of interconnection so that density is increased or sparsity is made more sparse. In such a case, the universe would necessarily present an appearance in which wholes would be bounded by the relative sparseness of their interconnection. [Back to text]

*4 The story is worth repeating. Wallace was a young naturalist who, in 1856 (three years before the publication of Darwin's *Origin*), while in the rain forests of Ternate, Indonesia, had an attack of malaria and, following delirium, a psychedelic experience in which he discovered the principle of natural selection. He wrote this out in a long letter to Darwin. In this letter he explained his discovery in the following words: "The action of this principle is exactly like that of the centrifugal governor of the steam engine, which checks and corrects any irregularities almost before they become evident; and in like manner no unbalanced deficiency in the animal kingdom can ever reach any conspicuous magnitude because it would make itself felt at the very first step, by rendering existence difficult and extinction almost sure to follow."
(Reprinted in *Darwin, a Norton Critical Edition*, ED. Philip Appleman, W. W. Norton, 1970). [Back to text]

*5 Notice the use of physical metaphor, inappropriate to the creatural phenomena being discussed. Indeed, it may be argued that this whole comparison between social biological matters, on the one hand, and physical process, on the other, is a monstrous use of inappropriate metaphor. [Back to text]

*6 Lucretius, *On the Nature of the Universe,* translated by Ronald E. Lathan (Baltimore: Penguin Books) [Back to text]

*7 I use the phrase, to map onto, for the following reasons: All description, explanation, or representation is necessarily in some sense a mapping of derivatives from the phenomena to be described onto some surface of matrix or system or coordinates. In the case of an actual map, the receiving matrix is commonly a flat sheet of paper of finite extent, and difficulties occur when that which is to be mapped is too big or, for example, spherical. Other difficulties would be generate if the receiving matrix were the surface of a torus (doughnut) or if it were a discontinuous lineal sequence of points. Every receiving matrix, even a language or a tautological network of propositions, will have its formal characteristics which will in principle be distortive of the phenomena to be mapped onto it. The universe was, perhaps, designed by Procrustes, that sinister character of Greek mythology in whose inn every traveler had to fit the bed on pain of amputation or elongation of the legs. [Back to text]

*8 So quoted by Warren McCulloch in *Embodiments of Mind* (Cambridge: MIT Press, 1965.) [Back to text]

*9 Bertrand Russell's concept of logical type will be discussed in some detail later, especially in the final section of Chapter 4. For the present, understand that because a class cannot be a member of itself, conclusions that can be drawn only from multiple cases (e.g. , from differences between pairs of items) are of different logical type from conclusions drawn from a single item (e.g., from a quantity). (Also see Glossary.) [Back to text]

I INTRODUCTION

III Multiple Versions of the World

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III MULTIPLE VERSIONS OF THE WORLD

What I tell you three times is true.
– LEWIS CARROLL, *The Hunting of the Snark*

Chapter 2, "Every Schoolboy Knows . . ." has introduced the reader to a number of basic ideas about the world, elementary propositions or verities with which every serious epistemology or epistemologist must make peace.

In this chapter, I go on to generalizations that are somewhat more complex in that the question which I ask takes the immediate, exoteric form: "What bonus or increment of knowing follows from *combining* information from two or more sources?"

The reader may take the present chapter and Chapter 5 "Multiple Versions of Relationship" as just two more items which the schoolboy should know. And in fact, in the writing of the book, the heading "Two descriptions are better than one" originally covered all this material. But as the more or less experimental writing of the book went on over about three years, this heading aggregated to itself a very considerable range of sections, and it became evident that the combination of diverse pieces of information defined an approach of very great power to what I call (in Chapter 1) "the pattern which connects." Particular facets of the pattern were brought to my attention by particular ways in which two or more pieces of information could be combined.

In the present chapter, I shall focus on those varieties of combination which would seem to give the perceiving organism information about the world around itself or about itself as a part of that external world (as when the creature sees its own toe). I shall leave for Chapter 5 the more subtle and, indeed, more biological or creatural combinations that would give the perceiver more knowledge of the internal relations and processes called the *self*.

In every instance, the primary question I shall ask will concern the bonus of understanding which the combination of information affords. The reader is, however, reminded that behind the simple, superficial question there is partly concealed the deeper and perhaps mystical question, "Does the study of this particular case, in which an insight developed from the comparison of sources, throw any light on how the universe is integrated?" My method of procedure will be to ask about the immediate bonus in each case, but my ultimate goal is an inquiry into the larger pattern which connects.

1.THE CASE OF DIFFERENCE

Of all these examples, the simplest but the most profound is the fact that it takes at least two somethings to create a difference. To produce news of difference, *i.e., information,* there must be two entities (real or imagined) such that the difference between them can be immanent in their mutual relationship; and the whole affair must be such that news of their difference can be represented as a difference inside some information-processing entity, such as a brain or, perhaps, a computer.

There is a profound and unanswerable question about the nature of those "at least two" things that between them generate the difference which becomes information by making a difference. Clearly each alone is – for the mind and perception – a non-entity, a non-being. Not different from being, and not different from non-being. An unknowable, a *Ding an sich*, a sound of one hand clapping.

The stuff of sensation, then, is a pair of values of some variable, presented over a time to a sense organ whose response depends upon the ratio between the members of the pair. (This matter of the nature of difference will be discussed in detail in Chapter 4, criterion 2.)

2. THE CASE OF BINOCULAR VISION

Let us consider another simple and familiar case of double description. What is gained by comparing the data collected by one eye with the data collected by the other? Typically, both eyes are aimed at the same region of the surrounding universe, and this might seem to be a wasteful use of the sense organs. But the anatomy indicate that very considerable advantage must accrue from this usage. The innervation of the two retinas and the creation at the optic chiasma of pathways for the redistribution of information is such an extraordinary feat of morphogenesis as must surely denote great evolutionary advantage.

In brief, each retinal surface is a nearly hemispherical cup into which a lens focuses an inverted image of what is being seen. Thus, the image of what is over to the left front will be focused onto the outer side of the right retina and onto the inner side of the left retina. What is surprising is that the innervation of each retina is divided into two systems by a sharp vertical boundary. Thus, the information carried by optic fibers from the outside of the right eye meets, in the right brain, with the information carried by fibers from the inner side of the left eye. Similarly, information from the outside of the left retina and the inside of the right retina is gathered in the left brain.

The binocular image, which appears to be undivided, is in fact a complex synthesis of information from the left front in the right brain and a corresponding synthesis of material from the right front in the left brain. Later these two synthesized aggregates of information are themselves synthesized into a single subjective picture from which all traces of the vertical boundary have disappeared.

From this elaborate arrangement, two sorts of advantage accrue. The seer is able to improve resolution at edges and contrasts; and better able to read when

Figure 4

the print is small or the illumination poor. More important, information about depth is created. In more formal language, the *difference* between the information provided by the one retina and that provided by the other is itself information of a *different logical type.* From this new sort of information, the seer adds an extra *dimension* to seeing.

In Figure 4, let *A* represent the class or set of components of the aggregate of information obtained from some first source (e.g., the right eye), and let *B* represent the class of components of the information obtained from some second source (e.g., the left eye). Then *AB* will represent the class of components referred to by information from both eyes. *AB* must either contain members or be empty.

If there exist real members of *AB,* then the information from the second source has imposed a sub-classification upon *A* that was previously impossible (i.e., has provided, in combination with *A,* a logical type of information of which the first source alone was incapable).

We now proceed with the search for other cases under this general rubric and shall specifically look in each case for the genesis of information of new logical type out of the juxtaposing of multiple descriptions. In principle, extra "depth" in some metaphoric sense is to be expected whenever the information for the two descriptions is differently collected or differently coded.

3. THE CASE OF THE PLANET PLUTO

Human sense organs can receive *only* news of difference, and the differences must be coded into events in *time* (i.e., into *changes)* in order to be perceptible. Ordinary static differences that remain constant for more than a few seconds become perceptible, only by scanning. Similarly, very slow changes become perceptible only by a combination of scanning *and* bringing together observations from separated moments in the continuum of time.

An elegant (i.e., an economical) example of these principles is provided by the device used by Clyde William Tombaugh, who in 1930, while still a graduate student, discovered the planet Pluto.

From calculations based on disturbances in the orbit of Neptune it seemed that these irregularities could be explained by gravitational pull from some planet in an orbit outside the orbit of Neptune. The calculations indicated in what region of the sky the new planet could be expected at a given time.

The Object to be looked for would certainly be very small and dim (about 15th magnitude), and its appearance would differ from that of other objects in the sky only in the fact of very slow movement, so slow as to be quite imperceptible to the human eye.

This problem was solved by the use of an instrument which astronomers call a *blinker*. Photographs of appropriate region of the sky were taken at longish intervals. These photographs were then studied in pairs in the blinker. This instrument is the converse of a binocular microscope; instead of two eyepieces and one stage, it has one eyepiece and two stages and is so arranged that by the flick of a lever, what is seen at one moment on one stage can be replaced by a view of the other stage. Two photographs are placed in exact register on the two stages so that all the ordinary fixed stars precisely coincide. Then, when the lever is flicked over, the fixed stars will not appear to move, but a planet will appear to jump from one position to another. There were, however, many jumping objects (asteroids) in the field of the photographs, and Tombaugh had to find one that jumped *less* than the others.

After hundreds of such comparisons, Tombaugh saw Pluto jump.

4. THE CASE OF SYNAPTIC SUMMATION

Synaptic summation is the technical term used in neurophysiology for those instances in which some neuron C is fired only by a combination of neurons A and B. A alone is insufficient to fire C, and B alone is insufficient to fire C; but if neurons A and B fire together within a limited period of microseconds, then C is triggered (see Figure 5). Notice that the conventional term for this phenomenon, *summation*, would suggest an *adding* of information from one source to information from another. What actually happens is not an adding but a forming of a logical product, a process more closely akin to multiplication.

Figure 5

What this arrangement does to the information that neuron A alone could give is a segmentation or sub-classification of the firings of A into two classes, namely, those firings of A accompanied by B and those firings of A which are not accompanied by B. Correspondingly, the firings of neuron B are subdivided into two classes, those accompanied by A and those not accompanied by A.

5. THE CASE OF THE HALLUCINATED DAGGER

Macbeth is about to murder Duncan, and in horror at his deed, he hallucinates a dagger (Act II, scene I).

Is this a dagger which I see before me,
The handle toward my hand? Come, let me clutch thee.
I have thee not, and yet see thee still.
Art thou not, fatal vision, sensible
To feeling as to sight? Or art thou but
A dagger of the mind, a false creation,
Proceeding form the heat-oppressed brain?
I see thee yet, in form as palpable
As this which now I draw.
Thou marchall’st me the way that I was going;
And such an instrument I was to use.
Mine eyes are made the fools o’ the other senses,
Or else worth all the rest: I see thee still;
And on thy blade and dudgeon gouts of blood,
Which was not so before. There’s no such thing:
It is the bloody business which informs
Thus to mine eyes.

This literary example will serve for all those cases of double description in which data from two or more different senses are combined. Macbeth "proves" that the dagger is only an hallucination by checking with his sense of touch, but even that is not enough. Perhaps his eyes are "worth all the rest." It is only when "gouts of blood" appear on the hallucinated dagger that he can dismiss the whole matter: "There’s no such thing."

Comparison of information form one sense with information from another, combined with change in the hallucination, has offered Macbeth the metainformation that his experience was imaginary. In terms of Figure 4, *AB* was an empty set.

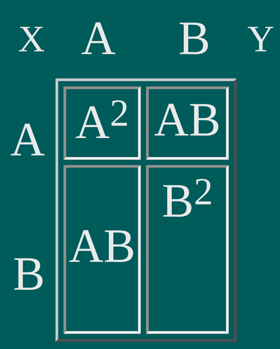
6. THE CASE OF SYNONYMOUS LANGUAGES

In many cases, an increment of insight is provided by a second language of description without the addition of any extra so-called objective information. Two proofs of a given mathematical theorem may combine to give the student an extra grasp of the relation which is being demonstrated.

Every schoolboy knows that $(a + b)^2 = a^2 + 2ab + b^2$, and he may be aware that this algebraic equation is a first step in a massive branch of mathematics called *binominal theory*. The equation itself is sufficiently demonstrated by the algorithm of algebraic multiplication, each step of which is in accord with the definitions and postulates of the tautology called *algebra* – that whose subject matter is the expansion and analysis of the notion "any."

But many schoolboys do not know that there is a geometric demonstration of the same binomial expansion (see Figure 6). Consider the straight line *XY*, and let this line be composed of two segments, a and b. The line is now a geometric representation of $(a + b)$ and the square constructed upon XY will be $(a + b)^2$; that is, it will have an *area called* "$(a + b)^2$."

This square can now be dissected by marking off



the length *a* along the line *XY* and along one of the adjacent sides of the square. The schoolboy can now think that he sees that the square is cut up into four pieces. There are two squares, one of which is a^2 while the other is b^2, and two rectangles, each of which is of area $(a \times b)$ (i.e., $2ab$).

Thus, the familiar algebraic equation $(a + b)^2 = a^2 + 2ab + b^2$ also seems to be true in Euclidean geometry. But surely it was too much to hope for that the separate pieces of the quantity $a^2 + 2ab + b^2$ would still be neatly separate in the geometric translation.

But what has been said? By what right did we substitute a so-called "length" for *a* and another for *b* and assume that, placed end to end, they would make a straight line $(a + b)$ and so on? Are we *sure* that the lengths of lines obey arithmetic rules? What has the schoolboy learned form our stating the same old equation in a new language?

In a certain sense, *nothing* has been added. No new information has been generated or captured by my asserting that $(a + b)^2 = a^2 + 2ab + b^2$ in geometry as well as in algebra.

Does a *language*, then, as such, contain *no* information?

But even if, mathematically, nothing has been added by the little mathematical conjuring trick, I still believe that the schoolboy who has never seen that the trick could be played will have a chance to learn something when the trick is shown. There is a contribution to didactic method. The discovery (if it be discovery) that the two languages (of algebra and of geometry) are mutually translatable is itself an *enlightenment.*

Another mathematical example may help the reader to assimilate the effect of using two languages.*

Ask your friends, "What is the sum of the first ten odd numbers?"

The answers will probably be statements of ignorance or attempts to add up the series:

1 + 3 + 5 + 7 + 9 + 11 + 13 + 15 + 17 + 19

Show them that:

The sum of the first odd number is 1.
The sum of the first two odd numbers is 4.
The sum of the first three odd numbers is 9.
The sum of the first four odd numbers is 16.
The sum of the first five odd numbers is 25.

And so on.

Rather soon, your friends will say something like, "Oh, then the sum of the first ten odd numbers must be 100." They have learned the *trick* for adding series of odd numbers.

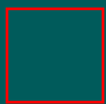
But ask for an explanation of why this trick *must* work and the average nonmathematician will be unable to answer. (And the state of elementary education is such that many will have no idea of how to proceed in order to create an answer.)

What has to be discovered is the difference between the *ordinal name* of the given odd number and its *cardinal* value – a difference in a logical type! We are accustomed to expect that the name of a numeral will be the same as its numerical value.[*2] But indeed, in this case, the name is not the same as the thing named.

For example, the sum of the first five odd numbers *minus* the sum of first four odd numbers must equal $5^2 - 4^2$. At the same time, we must notice that, of course, the difference between the two sums is indeed the odd number that was last added to the stack. In other words, this last added number must be equal to the difference between the squares.

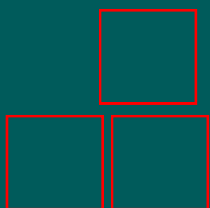
Consider the same matter in a visual language. We have to demonstrate that the *next* odd number will always add to the sum of the previous odd numbers just enough to make the next total square of the ordinal name of that odd number.

Represent the first odd number (1) with a unit square:



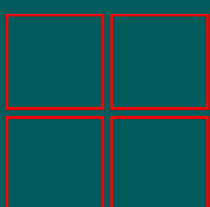
1

Represent the second odd number (3) with three unit squares:



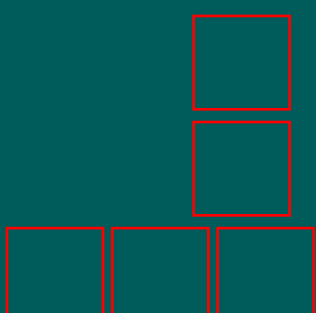
3

Add the two figures together:



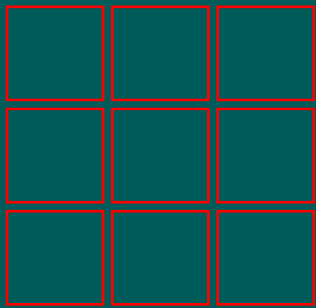
1 + 3 = 4

Represent the third odd number (5) with five unit squares:



5

Add this to the previous figure:



1 + 3 + 5 = 9

Figure 7

That is, 4 + 5 = 9.

And so on. The visual presentation makes it rather easy to combine ordinals, cardinals, and the regularities of summing the series.

What has happened is that the use of a system of geometric metaphor has enormously facilitated understanding of *how* the mechanical trick comes to be a rule or regularity. More important, the student has been made aware of the contrast between applying a trick and understanding the necessity of truth behind the trick. And still more important, the student has, perhaps unwittingly, had the experience of the leap from talking arithmetic to talking *about* arithmetic, Not *numbers* but *numbers of numbers.*

It was *then*, in Wallace Steven's words,

> *That the grapes seemed fatter.*
> *The fox ran out of his hole.*

7. THE CASE OF THE TWO SEXES

Von Neumann once remarked, partly in jest, that for self-replication among machines, it would be a necessary condition that two machines should act in collaboration.

Fission with replication is certainly a basic requirement of life, whether it be fore multiplication or for growth, and the biochemists now know broadly the process of replication of DNA. But next comes differentiation, whether it be the (surely) random generation of variety in evolution or the ordered differentiation of embryology. Fission, seemingly, *must* be punctuated by fusion, a general truth with exemplifies the principle of information processing we are considering here: namely that two sources of information (often in contrasting modes or languages) are enormously better than one.

At the bacterial level and even among protozoa and some fungi and algae, the gametes remain superficially identical; but in all metazoa and plants above the fungal level, the *sexes* of the gametes are distinguishable one from the other.

The binary differentiation of gametes, usually one sessile and one mobile, comes first. Following this comes the differentiation into two kinds of the multicellular individuals who are the producers of the two kinds of gametes.

Finally, there are the more complex cycles called *alternation of generations* in many plants and animal parasites.

All these orders of differentiation are surely related to the informational economics of fission, fusion and sexual dimorphism.

So, returning to the most primitive fission and fusion, we note that the first effect or contribution of fusion to the economics of genetic information is presumably some sort of *checking*.

The process of chromosomal fusion is essentially the same in all plants and animals, and wherever it occurs, the corresponding strings of DNA material are set side by side and, in a functional sense, are *compared*. If differences between the strings of material from the respective gametes are too great, fertilization (so called) cannot occur.[*3]

In the total process of evolution, fusion, which is the central fact of sex, has the function of limiting genetic variability. Gametes that, for whatever reason, be it mutation or other, are too different from the statistical norm are likely to meet in sexual fusion with more normal gametes of opposite sex, and in this meeting, the extremes of deviation will be eliminated. (Note, in passing, that this need to eliminate deviation is likely to be imperfectly met in "incestuous" mating between gametes from closely related sources.)

But although one important function of the fusion of gametes in sexual reproduction would seem to be the limitation of deviance, it is also necessary to stress the contrary function: increasing phenotypic variety. The fusion of random pairs of gametes assures that the gene pool of the participating population will be homogeneous in the sense of being well mixed. At the same time, it assures that every viable genic combination within that pool shall be created. That is, every viable gene is tested in conjunction with as many other constellations of other genes as is possible within the limits of the participating population.

As usual in the panorama of evolution, we find that the single process is Janus-like, facing in two directions. In the present case, the fusion of gametes both places a limitation on individual deviance and ensures the multiple recombination of genetic material.

8. THE CASE OF BEATS AND MOIRÉ PHENOMENA

Interesting phenomena occur when two or more rhythmic patterns are combined, and these phenomena illustrate very aptly the enrichment of information that occurs when one description is combined with another. In the case of rhythmic patterns, the combination of two such patterns will generate a third. Therefore, it becomes possible to investigate an unfamiliar pattern by combining it with a known second pattern and inspecting the third pattern which they together generate.

The simplest case of what I am calling the *moiré phenomenon* is the well-known production of beats when two sounds of different frequency are combined. The phenomenon is explained by mapping onto simple arithmetic, according to the rule that if one note produces a peak in every n time units and the other has a peak in every m time units, then the combination will produce a *beat* in every m x n units when the peaks coincide. The combination has obvious uses in piano tuning. Similarly, it is possible to combine two sounds of very high frequency in order to produce beats of frequency low enough to be heard by the human ear. Sonar devices that operate on this principle are now available for the blind. A beam of high-frequency sound is emitted, and the echoes that this beam generates are received back into an "ear" in which a lower but still inaudible frequency is being generated. The resulting beats are then passed on to the human ear.

The matter becomes more complex when the rhythmic patterns, instead of being limited, as frequency is, to the single dimension of time, exist in two or more dimensions. In such cases, the result of combining the two patterns may be surprising.

Three principles are illustrated by these moiré phenomena: First, any two patterns may, if appropriately combined, generate a third. Second, any two of these three patterns could serve as base for a description of the third. Third, the whole problem of defining what is meant by the word *pattern* can be approached through these phenomena. Do we, in fact, carry around with us (like the blind person's sonar) samples of information (news of regular differences) that comes in from outside? Do we, for example, use our habits of what is called "dependency" to test the characteristics of other persons?

Do animals (and even plants) have characteristics such that in a given niche there is a testing of that niche by something like the moiré phenomenon?

Other questions arise regarding the nature of *aesthetic* experience. Poetry, dance, music, and other rhythmic phenomena are certainly very archaic and probably more ancient than prose. It is, moreover, characteristic of the archaic behaviors and perceptions that rhythm is continually modulated; that is, the poetry or music contains materials that could be processed by superposing *comparison* by any receiving organism with a few seconds of memory.

Is it possible that this worldwide artistic, poetical, and musical phenomenon is somehow related to moiré? If so, then the individual mind is surely deeply organized in ways which a consideration of moiré phenomena will help us to understand. In terms of the definition of "explanation" proposed in section 9, we shall say that the formal mathematics or "logic" of moiré may provide an appropriate tautology onto which these aesthetic phenomena could be mapped.

9. THE CASE OF "DESCRIPTION," "TAUTOLOGY," AND "EXPLANATION"

Among human beings, description and explanation are both highly valued, but this example of doubled information differs from most of the other cases offered in this chapter in that explanation contains no new information different from what was present in the description. Indeed, a great deal of the information that was present in description is commonly thrown away, and only a rather small part of what was to be explained is, in fact, explained. But explanation is certainly of enormous importance and certainly seems to give a bonus of insight over and above what was contained in description. Is the bonus of insight which explanation gives somehow related to what we got from combining two languages in section 6, above?

To examine this case, it is necessary first briefly to indicate definitions for the three words: *description*, *tautology*, and *explanation*.

A pure description would include all the facts (i.e., all the effective differences) immanent in the phenomena to be described but would indicate no kind of connection among these phenomena that might make them more understandable. For example, a film with sound and perhaps recordings of smell and other sense data might constitute a complete or sufficient description of what happened in front of a battery of cameras at a certain time. But that film will do little to connect the events shown on the screen one with another and will not by itself furnish any explanation. On the other hand, an explanation can be total without being descriptive. "God made everything there is" is totally explanatory but does not tell you anything about any of the things or their relations.

In science, these two types of organization of data (description and explanation) are connected by what is technically called tautology. Examples of tautology range from the simplest case, the assertion that "If P is true, then P is true," to such elaborate structures as the geometry of Euclid, where "If the axioms and postulates are true, then Pythagoras' theorem is true." Another example would be the axioms, definitions, postulates, and theorems of Von Neumann's Theory of Games. In such an aggregate of postulates and axioms and theorems, it is of course not claimed that any of the axioms or theorems is in any sense "true" independently or true in the outside world.

Indeed, Von Neumann, in his famous book,[*4] expressly points out the differences between his tautological world and the more complex would of human relations. All that is claimed is that if the axioms be such and such and the postulates such and such, then the theorems will be so and so. In others words, all that the tautology affords is *connections between propositions*. The creator of the tautology stakes his reputation on the validity of these connections.

Tautology contains no information whatsoever, and explanation (the mapping of description onto tautology) contains only the information that was present in the description. The "mapping" asserts implicitly that the links which hold the tautology together correspond to relations which obtain in the description. Description, on the other hand, contains information but no logic and no explanation. For some reason, human beings enormously value this combining of ways of organizing information or material.

To illustrate how description, tautology, and explanation fit together, let me cite an assignment which I have given several times to classes. I am indebted to the astronomer Jeff Scargle for this problem, but I am responsible for the solution. The problem is:

A man is shaving with his razor in his right had. He looks into his mirror and in the mirror sees his image shaving with its left hand. He says, "Oh. There's been a reversal of right and left. Why is there no reversal of top and bottom?"

The problem was presented to the students in this form, and they were asked to unravel the muddle in which the man evidently is and to discuss the nature of explanation after they have accomplished this.

There are at least two twists in the problem as set. One gimmick distracts the student to focus on the *right* and *left*. In fact, what has been reversed is front and back, not *right* and *left*. But there is a more subtle trouble behind that, namely, that the words right and left are not in the same language as the words *top* and *bottom*. *Right* and *left* are words of an inner language; whereas *top* and *bottom* are parts of an external language. If the man is looking south and his image is looking north, the top is upward in himself and is upward in his image. His east side is on the east side in the image, and his west side is on the west side in the image. *East* and *west* are in the same language as top and bottom; whereas *right* and *left* are in different language. There is thus a logical trap in the problem as set.

It is necessary to understand that right and left cannot be defined and that you will meet with a lot of trouble if you try to define such words. If you go to the Oxford English Dictionary, you will find that left is defined as "distinctive epithet of the hand which is normally the weaker." The dictionary maker openly shows his embarrassment. If you go to Webster, you will find a more useful definition, but the author cheats. One of the rules of writing a dictionary is that you can not rely on ostensive communication for your main definition. So the problem is to define *left* without pointing to an asymmetrical object. Webster (1959) says, "that side of one's body which is toward the west when one faces north, usually the side of the less-used hand." This is using the asymmetry of the spinning earth.

In truth, the definition cannot be done without cheating. *Asymmetry* is easy to define, but there are no verbal means – and there *can* be none – for indicating which of two (mirror-image) halves is intended.

An explanation has to provide something more than a description provides and, in the end, an explanation appeals to a *tautology*, which, as I have defined it, is a body of propositions so linked together that the links *between the propositions* are necessarily valid.

The simplest tautology is "If P is true, then P is true."

A more complex tautology would be "If Q follows from P, then Q follows from P." From there, you can build up into whatever complexity you like. But you are still within the domain of the *if* clause provided, not by data, but by *you.* That is a tautology.

Now, an explanation is a mapping of the pieces of a description onto a tautology, and an explanation becomes acceptable to the degree that you are willing and able to accept the links of the tautology. If the links are "self-evident" (i.e., if they seem undoubtable to the self that is you), then the explanation built on that tautology is satisfactory to you. That is all. It is always a matter of natural history, a matter of the faith, imagination, trust, rigidity, and so on of the organism, that is of you or me.

Let us consider what sort of tautology will serve as a foundation for our description of mirror images and their asymmetry.

Your right hand is an asymmetrical, three-dimensional object; and to define it, you require information that will link at least three polarities. To make it different from a left hand, three binary descriptive clauses must be fixed. Direction toward the palm must be distinguished form direction toward the back of the hand; direction toward the elbow must be distinguished from direction toward the fingertips; direction toward the thumb must be distinguished from direction toward the fifth finger. Now build the tautology to assert that a reversal of any one of these three binary descriptive propositions will create the mirror image (the stereo-opposite) of the hand form which we started (i.e., will create a "left" hand).

If you place your hands palm to palm so that the right palm faces north, the left will face south, and you will get a case similar to that of the man shaving.

Now, the central postulate of our tautology is that *reversal in one dimension always generates the stereo-opposite.* From this postulate, it follows – can you doubt it? – that reversal in *two* dimensions will generate the opposite of the opposite (i.e., will take us back to the form from which we started). Reversal in three dimensions will again generate the stereo-opposite. And so on.

We now flesh out our explanation by the process which the American logician, C. S. Peirce called *abduction*, that is, by finding other relevant phenomena and arguing that these, too, are cases under our rule and can be mapped onto the same tautology.

Imagine that you are an old-fashioned photographer with a black cloth over your head. You look into your camera at the ground-glass screen on which you see the face of the man whose portrait you are making. The lens is between the ground-glass screen and the subject.

On the screen, you will see the image upside down and right for left but still facing you. If the subject is holding something in his right hand, he will still be holding it in his right hand on the screen but rotated 180 degrees.

If now you make a hole in the front of the camera and look in at the image formed on the ground-glass screen or on the film, the top of his head will be at the bottom. His chin will be at the top. His left will be over to the right side, *and* now he is facing himself. You have reversed three dimensions. So now you see again his stereo-opposite.

Explanation, then, consists in building a tautology, ensuring as best as you can the validity of the links in the tautology so that it seems to you to be self-evident, which is in the end never totally satisfactory because nobody knows what will be discovered later.

If explanation is as I have described it, we may well wonder what bonus human beings get from achieving such a cumbersome and indeed seemingly unprofitable rigamarole.

This is a question of natural history, and I believe that the problem is at least partly solved when we observe that human beings are very careless in their construction of the tautologies on which to base their explanation. In such a case, one would suppose that the bonus would be negative; but this seems not to be so, judging by the popularity of explanations which are so informal as to be misleading. A common form of empty explanation is the appeal to what I have called "dormitive principles", borrowing the word *dormitive* from Molière. There is a coda in dog Latin to Molière’s *Le Malade Imaginaire*, and in this coda, we se on the stage a medieval oral doctoral examination. The examiners ask the candidate why opium puts people to sleep. The candidate triumphantly answers, "Because, learned doctors, it contains a dormitive principle."

We can imagine the candidate spending the rest of his life fractionating opium in a biochemistry lab and successively identifying in which fraction the so-called dormitive principle remained.

A better answer to the doctors’ question would involve, not the opium alone, but a relationship between the opium and the people. In other words, the dormitive explanation actually falsifies the true facts of the case but what is, I believe, important is that dormitive explanations still *permit abduction.* Having enunciated a generality that opium contains a dormitive principle, it is then possible to use this type of phrasing for a very large number of other phenomena. We can say, for example, that adrenalin contains an enlivening principle and reserpine a tranquilizing principle. This will give us, albeit inaccurately and epistemologically unacceptably, handles with which to grab at a very large number of phenomena that appear to be formally comparable. And, indeed, they are formally comparable to this extent, that invoking a principle *inside one component* is in fact the error that is made in every one of these cases.

The fact remains that as a matter of natural history – and we are as interested in natural history as we are in strict epistemology – abduction is a great comfort to people, and formal explanation is often a bore. "Man thinks in two kinds of terms: one, the natural terms, shared with beasts; the other, the conventinal terms (the logicals) enjoyed by man alone." *5

This chapter has examined various ways in which the combining of information of different sorts or from different sources results in something more than addition. The aggregate is greater than the sum of its parts because the combining of the parts is not a simple adding but is of the nature of a multiplication or a fractionation, or the creation of a logical product. A momentary gleam of enlightenment.

So to complete this chapter and before attempting even a listing of the criteria of mental process, it is appropriate to look briefly at this structure in a much more personal and more universal way.

I have consistently held my language to an "intellectual" or "objective" mode, and this mode is convenient for many purposes (only to be avoided when used to avoid recognition of the observer's bias and stance).

To put away the quasi objective, at least in part, is not difficult, and such a change in mode is proposed by such question as: What is this book about? What is its personal meaning to me? What am I trying to say or to discover?

The question "What am I trying to discover?" is not as unanswerable as mystics would have us believe. From the manner of the search, we can read what sort of discovery the searcher may thereby reach; and knowing this, we may suspect that such a discovery is what the searcher secretly and unconsciously desires.

This chapter has defined and exemplified a *manner of search*, and therefore this is the moment to raise two questions: For what am I searching? To what questions have fifty years of science led me?

The manner of the search is plain to me and might be called the *method of double or multiple comparison.*

Consider the case of binocular vision. I compared what could be seen with one eye with what could be seen with two eyes and noted that in this comparison the two-eyed method of seeing disclosed an extra dimension called *depth*. But the two-eyed way of seeing is itself an act of comparison. In other words, the chapter has been a series of comparative studies of the comparative method. The section on binocular vision (section 2) was such a comparative studies of one method of comparison, and the section on catching Pluto (section 3) was another comparative study of the comparative method. Thus the whole chapter, in which such instances are placed side by side, became a display inviting the reader to achieve insight by comparing the instances one with another.

Finally, all that comparing of comparisons was built up to prepare author and reader of thought about problems of Natural Mind. There, too, we shall encounter creative comparison. It is the Platonic thesis of the book that epistemology is an indivisible, integrated meta-science whose subject matter is the world of evolution, thought, adaptation, embryology, and genetics – the science of mind in the widest sense of the word.*6

The comparing of these phenomena (comparing thought with evolution and epigenesis with both) is the *manner of search* of the science called "epistemology."

Or, in the phrasing of this chapter, we may say that epistemology is the bonus from combining insights form all these separate genetic sciences.

But epistemology is always and inevitably *personal*. The point of the probe is always in the heart of the explorer: What is *my* answer to the question of the nature of knowing? I surrender to the belief that my knowing is a small part of a wider integrated knowing that knits the entire biosphere or creation.

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* I am indebted to Gertrude Hendrix for this, to most people, unfamiliar regularity: Gertrude Hendrix, "Learning by Discovery," *The Mathematics Teacher* 54 (May 1961): 290-299. [Back to text]

*2 Alternatively, we may say that the number of numbers in a set is not the same as the sum of numbers in the same set. One way or the other, we encounter a discontinuity in logical typing. [Back to text]

*3 I believe that this was first argued by C.P. Martin in his *Psychology, Evolution and Sex*, 1956. Samuel Butler (in *More Notebooks of Samuel Butler*, edited by Festing Jones) made a similar point in discussion parthenogenesis. He argues that as dreams are to thought, so parthenogenesis is to sexual reproduction. Thought is stabilized and tested against the template of external reality, but dreams run loose. Similarly, parthenogenesis can be expected to run loose; whereas zygote formation is stabilized by the mutual comparison of gametes. [Back to text]

*4 Von Neumann, J., and Morgenstern, O., *The Theory of Games and Economic Behavior* (Princeton: Princeton University Press, 1944.) [Back to text]

*5 William of Ockham, 1280-1349, quoted by Warren McCulloch in his *Embodiments of Mind*, M.I.T. Press, 1965. [Back to text]

*6 The reader will perhaps notice that consciousness is missing from this list. I prefer to use that word, not as a general term, but specifically for that strange experience whereby we (and perhaps other mammals) are sometimes conscious of the products of our perception and thought but unconscious of the greater part of the processes. [Back to text]

I INTRODUCTION

II Every Schoolboy Knows …

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