HOMEOKINETICS - HOW THINGS WORK

by

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NR=Norrie Robbins
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HOMEOKINETICS - HOW THINGS WORK  
(Tales of Enlightenment for the Young; Moral Tales for the Mature)

What is ‘it’ all about?

A person who wants an education on how things work requires a guide. This small volume is an attempt to provide that function in very brief form. Readers are assumed to have an education, one by which they know they have had exposure to many ideas but sense that their education left them with no feeling of what 'it' - the total reality out there - is all about. In offering that service, in fairly complete form, this book will try to be both global and local in the scope of its stories, as it must be. The reader will find dealing with the material as difficult as learning to jog or to play the piano, no more, no less.

Chapter One - What is the Problem?

However if any one of the following statements is the core of your belief, this book is not for you.

1. God created this universe and all in it, and His design is not to be questioned or sought, only accepted.
2. Out there is only chaos, and no orderly explanation can be found. Perhaps each thing out there has its own little spirit, making up its own mind, a chaos in toto; perhaps there is only mindless chaos.
3. Every system perceived out there has its own causal or descriptive explanations and there can be no general laws or designs, only many bits and pieces.
4. Everything out there is only a figment of one's own imagination.

If any of the above are the basis of your beliefs, you accept a different standard of cause and effect and of predictability than we do, and we cannot dispute our differences.

But, if you are willing to show patience and follow the thread of our themes, we will attempt to show you a limited number of principles of operation and materials sufficient to account for all the forms and functions out there, and in fact within you too, because in our belief, what is out there is no different from what is inside all of us and that is why we can describe and model both inside and outside.

So, we offer you a general systems construct, one that claims that it is able to deal with organization at every level, from the smallest subatomic particle, to the living cell, to the complex living being, to Man organized culturally into society, to earth, star, galaxy, on up to the cosmos itself. Beyond? At present we cannot yet fully reach, although we can now speculate. So we start with a first principle, if you wish to explain the totality of processes and forms out there you must start with the laws of physics. Aristotle was responsible, 2500 years ago, for the definition of physics as the science of the laws of motion and change in systems.

The problem is that many people (most in fact) do not want to start with that difficult subject of study. It would be less strain, more comforting if some softer set of philosophic ideas could be assumed independent of (?), instead of (?) the laws of physics, and that somehow the laws of physics would simply fall out or, in some other way, be avoided. But we submit that physics is the only complete construct that deals with physical reality.
There are numerous attempts at a general science of systems that have tried to get around this requirement. To name a few: the Greek vision of the universe (their 'cosmogeny' of a universe of crystal spheres and of gods), Engels' dialectic materialism, of recent vintages Ashby's view of cybernetics, recent book by James Miller and by Bowler. But they cannot. Their constructs are not capable of dealing with the whole host of systems’ problems that physics has shown competence to deal with, starting from Newton's modeling of solar system motion and the motion of bodies and projectiles on earth. If they do not assume physics, they cannot do the physics problems. If they assume physics and a whole body of ideas beyond physics, they have likely been repetitious, irrelevant, or contradictory. Physics itself must be mined thoroughly.

We can first raise the large philosophic question in the following general form. How many large scale modeling constructs are known that can deal with reality out there? Historically we sense that there are only three: a mystical view of reality, a mathematical-logical view of reality, and a physical view of reality.

In the mystical view, the individual adopts whatever principle he or she chooses to order reality out there. It may be fragmented, inconsistent, incomplete, and it mayor may not be shared by many others. It does not have these sorts of constraints. One cannot throw out such a construct, because in fact it has been the basis of the individual beliefs of most people through all of Man's history. But by the nature of one sort of inconsistency or another, it cannot be shared in common or simply be abstractly communicated and shared objectively by a large number of people. It is idiosyncratic or apologetic with regard to absolute internal or external consistency. If, for example, one adopts the philosophic view that there is a moral purpose in creation, it is apparent to many other people that any conceivable moral purpose seems to be contradicted or circumvented too often to regard the notion as compelling. To the believer only one form of apologetics or another is practiced. Morality, if it exists, is the consequence of physical law, not the cause of physical law. At the end we shall show the connection.

The mathematical-logical view, on the other hand requires an absolute internally consistent view (whatever that means - for details one must read in meta-mathematics - see for example, Benacerref and Putnam's Philosophy of Mathematics; or the October 1979 Scientific American discusses the mathematical outlook toward its problems).

The physical view is more restrictive. It requires scrupulous consistency, externally between internal 'explanation' and external observation, and requires an absolute parsimony of principles (and more recently of materials). Occam's Razor, the parsimony of assumption, becomes a primary metaphysical principle. Don't make more assumptions than you have to.

We would argue that the inability of sharing and communicating a set of common mystical principles to all, that can deal with all observable phenomena in an unambiguous 'predictive' detailed way, from a shared perception of the principles, is what eliminates mysticism as a general 'scientific' (parsimonious, general, predictive) basis for explanation even though most people hold such views.

Secondly, if the world out there were static, unmoving, then the mathematical-logical explanations of reality out there would hold the stage of theory. (Regardless of what appeared out there, the mind could likely succeed in encompassing it by a self-consistent construct.) However, if once we note that atoms exist (e.g., a view that sharpened in focus from its Greek origins), then their dynamics - not the dynamics of internal spirits - made the logical-mathematical view untenable as a general construct, and left one only with the constructive view of physical law and its constraints.
Actually what does a physical view of a system and how things work mean? We will provide an answer by real metaphors. We will refer to them as 'beaker' stories, stories that relate ‘just so’ to what we find in a container.

First Story. Imagine a container, e.g., a beaker. Into the beaker we introduce a few atoms. A physicist should be able to tell the story of what happens to those atoms within the beaker and how they interact (note the word, interact, meaning to act-among-themselves) and also react with the walls of the beaker. Clearly this is a physicist's story.

Second Story. Imagine a beaker filled with water. Sprinkle some salt or sugar into the beaker. A physicist should be able to tell the story of what happens to those molecules (or particles) of sugar or salt as they go into solution and interact with the molecules of water and the walls of the beaker.

Third Story. Imagine a beaker of water with a few 'nutrient' chemicals dissolved in the beaker. Into the beaker, introduce one bacterium. A physicist should be able to tell the story of what happens to the bacterial colony that will develop in that beaker as the bacteria interact with the nutrients and the walls of that beaker.

Fourth Story. Imagine a 'beaker' (this is imagined now to be a river valley on earth) into which one introduces a small colony of members of a higher living species, e.g., grass, trees, mice, *Homo sapiens*. A physicist should be able to tell something about the process of interaction of the species members, over generations, within that enclosure.

Fifth Story. Imagine a modern form of such a 'beaker' (for example, any of the large land masses on earth) on which social living forms - Man - exists, bound as human colonies into place, to form interactive urban centers, immersed in an agricultural support environment, with a national polity, or national polities, interacting within an international trading 'ecumene.' A physicist ought to be able to tell you about the interactive processes going on in such a beaker.

We accept these charges. Yes, that is what this book is about; that is the problem which is going to be explored - how do we account for things working at these systems levels and the very many other levels of organization that we perceive.

Clearly, if we tell you that all of nature is organized, first, at the following six primary levels:

- the cosmos
- galaxies
- galactic fragments - made up of dust, stars, gas, planets, other
  - quasi-stellar objects
- atoms - ions - molecules
- nuclear particles - either nuclei, electrons, or neutrinos
- protons - electrons - neutrons - neutrinos
- leptons -quarks

there is little doubt that all of these levels of phenomena are to be dealt with by physics. Scientific American each month attempts to make their stories comprehensible to the educated layman, scientific or not. But if we become a little more parochial and refer to the local arrangements

- stars (e.g., our sun)
- planets (e.g., our solar system)
  - planetary subsystems - lithosphere, hydrosphere, atmosphere, geochemical-biochemical sphere
- geographies - ecologies
we sense that many of these more parochial systems ought to be discussed by physical science, but we are bewildered at the thought of by what sort of science or how physics might reach out fundamentally to biology and social science. We have been led to believe that such fields require 'other' kinds of science, other than physics - physics may be a science of dead flies, but not live flies. However, we intend to show you that only one basic science exists, physics, and we intend to show you its extension, from simple systems, to complex systems by what we call homeokinetic physics. That physics does not abolish the other sciences; it acts as the foundation on which the other sciences can build, confidently, with great detail, if and only if they accept the basic principles of homeokinetic physics. Physics, pure and simple, is about simple systems; homeokinetic physics is about complex systems.

That is our purpose - to show that only one parsimonious science can reach all systems. Read on, fear not, we shall not overwhelm you in abstractions, only with reasonable ideas and illustrative metaphors.
Chapter Two - The Model For a Simple System

All systems are made up of a large number of small active players, atomisms. (An ism is not only a doctrine; it may also be the embodiment, witness organism.) In some cases all the players may be alike, in some cases there may be a considerable number of different players. As a result of interactive and cooperative actions among the players, the system undergoes its play. There really is nothing more. In a real sense the stories that can be told are as trite as the old movie formula: boy meets girl, boy loses girl, boy gets girl. On the other hand that formula made Hollywood for a number of generations, made the play or even the novel for even longer, and it manages to keep most people fascinated generation by generation. Now we have to elaborate the formula for all of the stories that make up the universe and all systems in it.

So we start from the very simplest form of the story. It really has all the elements of the general plot in it, but the story line can be followed most easily. Take a limp balloon, a paper bag, a soap bubble, or an empty small mouthed jar and blow it 'full' of air. First, we will tell about the system that results from those players introduced newly into the container, and second, we will tell you what happens to the system when the players are moved from place to place. The first describes the equilibrium, static or stationary state that emerges among the players. The second describes the dynamic states or phases of movement that the players can engage in cooperatively. Describe movement for one player? That we cannot do so simply. That requires a great deal of detailed physics. It is very simple to tell the common story of many players. The story of the one player has to be done in very specialized fashion. (The 'once upon a time' story of an individual is more complicated than the story of all the interactions going on in a group.)

Since the story of a group of atoms or molecules rushing into a container may sound boring, you might like to anticipate a human form - a group of people assembling for a cocktail party, people being crowded into a limited number of rooms, even people crowded onto spaceship Earth. There will be more detailing in the latter examples, but the gas molecules already tell much of the story.

First, we note that the gas molecules rush to fill out every part of the space accessible to them. There are barriers (the walls) they cannot cross. Second, pretty soon we note that if the number of players admitted is terminated and then the enclosure is shut, that in any direction we observe, we see as many players 'coming' as 'going,' yet they are all in continuing movement. Most precisely, they move, they stop (or 'collide') with their fellow members, spend a little time, move on. That motion was described by Einstein as a random walk motion. It was first observed experimentally as a Brownian motion of small particles in a liquid suspension. When it was first observed, people were not able to see atomic motions to observe the same form of motion, and they were not yet so willing to consider that 'free willed' people would act like otherwise inanimate matter (one might say that perhaps the cocktail had not yet been invented).

That Brownian particle-like motion - move, collide, share, move on, etc. - is what defines the motion and equalizes or equilibrates motion among all the particles. It creates the distribution characteristics of the ensemble of players.

What is that distribution? For this case of simple atomisms, atoms or molecules that we can regard as point atomisms, with shapes or innards that are not essential to our story, there are only three measures to the distribution. First, if the space is uniformly available to the atomisms, they fill up that space uniformly. Their density, that is either their number per volume or their mass per volume, in each region of space, is the same. Second, their 'pressure' is the same in each region of space. Pressure is a physical notion, so it has to be explained properly. The elementary definition would say it is how much force each side of an ensemble exerts on the
other side over a common unit of area of the face or gateway, separating the sides. This
equilibrium pressure is the same in all directions, for all separations of the total ensemble into
two sides. Thus, if one could measure that pressure or unit force by the force it would take to
push people (atomisms) from one room into another at the cocktail party, or, if we open a door to
the outside, we could measure the same force by what it would take to push new people into the
cocktail party enclosure.

Now actually, we were talking about atoms and molecules, not cocktail parties. The
same principle will hold in cocktail parties, but, as we shall discuss later, there is some more
process complexity to make up what we shall call 'social pressure.' Basically social pressure will
not be different from atomic pressure, but it will be augmented by the internal complexity of the
living atomisms. So it has been no idle metaphor we have provided by intimating a social
pressure, just one that hasn't yet been completed. For the simple atomisms (or for that 'weak'
component that can still be found in social pressure), the equilibrium pressure is a 'hydrostatic'
(fluid-like) pressure, a force which acts the same in every direction regardless of how the
ensemble is divided. It is the reason that the balloon, better still, the soap bubble blows up
uniformly when you blow new players into the container.

The third measure is the motional energy of the atomisms. That motional energy is called
kinetic energy. It is the total energy possessed by the ensemble because each atomism has some
of that energy as a motional energy. What does that mean?

If all the atomisms were standing still, we would say that they have no energy. There
would seem to be little that they could do. On the other hand, if they were each moving rapidly,
as they banged into each other they could do something. What? Well for example, if they were
all banging on one side of a door, for example a piston, and thereby creating a pressure, we could
see that they could move things, such as the piston and weights put on the piston. Creating
forces, moving weights, pushing them against their resistance to being moved is called doing
work. That kinetic energy of motion measures how much work the atomisms could do if they
were all directed in one direction rather than only randomly banging around among each other.
Such a definition is not idle, because in fact the atomisms can be made to do work. You had to
do work to blow up the balloon (ask your chest muscles), and that work could be recovered in a
rocket-like arrangement if you loosen the balloon opening.

Where did these three ensemble measures come from - uniform density uniform
hydrostatic pressure, uniform kinetic or motional energy?

They come from properties that were conserved during the collisions (or interactions)
among the atomisms. What physics says is that for point-like atomisms, there are only three
quantities that are conserved during and after collisions. These quantities are matter (matter, we
say, is neither created nor destroyed, at most only transformed); directed movement (technically
called momentum - momentum is neither created nor destroyed, only transformed); energy
(energy is neither created nor destroyed, only transformed).

It is a measure of the absolute parsimony of physics that it states that the only
autonomous variables that have to be considered in an ensemble are those associated with
atomistic interactions as conservations, and that these conservations are very few. This is our
second principle. In simple systems we need only deal with the three we have named. The
purpose of the development of more stories in subsequent chapters will be to bring the story of
interactions and their conservations up to the full complexity that faces us in examining the
whole universe and the totality of its processes.
The reader should have an uneasiness (perhaps the first - the purpose of this book is to bring out those uneasiness and try to explain them). If the entire play seemed to deal only with particles and their motion (number, momentum, energy of the particle players; density, pressure, energy of the ensemble of players) where did matter come from, where does the motion come from? At this point, we do not want to deal with the first question. Assume matter exists (you can read Weinberg’s *The First Three Minutes*, and have some sense of why matter after the first hundredth of a second after 'creation'). Perhaps at the end, in a blaze of glory, we will 'explain' to you where matter comes from. But from an elementary point of view, it has 'nearly always' been around, and our problem is to tell the story of how it associates and binds to higher and higher organized forms.

But it is reasonable for us to answer now where the motion comes from. The atomistic motion comes from the temperature of the wall of the enclosure. Where did that come from? From the surrounding systems on earth. And their temperature? From the sun. And its energy and temperature? Contributed by the galaxy. And from whence did the galaxy receive the matter, temperature, and energy? From the 'big bang' of creation of the cosmos.

That story line was stated much too cryptically. It contained many hidden words. But it is a hint, meant only to indicate that each system is embedded in a superior system, like a Chinese puzzle box, or nested Russian dolls, wherein governing authority flows from above. Now we just hint at the notion, for to simply state that the enclosure wall has a temperature will not fully exhibit the total up-down complexity between and among systems.

Given that a certain number of atomistic players are introduced into a volume, which consists of a number density per unit volume, then the wall temperature acts as a 'potential' for the atomistic motion. A 'potential' is a system (potential can be a noun or adjective) that is capable of doing work, or supplying energy to do work. How potentials store that capability, in toto, will require a great deal of explanation. The storage function of a potential will emerge a little at a time. Suffice it for the present to indicate that the potential of wall temperature is achieved from a radiation field.

This is one more aspect of the construct of physics. There are a limited number of force systems, that 'cause' motion, not more than four. These 'create' and govern all the motions and changes we find in the universe. They appear to have the remarkable property of acting at a distance, or influencing action at a distance. At least this was the Newtonian view. In modern physics, we have more nearly narrowed that action to an exchange action, that literally something is actually exchanged in all such interactions. But from a descriptive point of view, whether one uses one description (force causes motion), the other description (bodies interact in their motion by an exchange of some entity), or a mixed description, it will not make much difference. Just to introduce two of the four force systems (there are forces and exchange entities), we will name two as the force of universal gravity, and the force system of electrodynamics. As at a cocktail party, please simply say "How do you do?" (later you may ask what do you do, why, etc.).

The electrodynamic force system makes itself evident via the exchange form of electromagnetic radiation. The exchange entities are known as photons, which you know as beams of light or heat energy. (Invisible heat energy, or radio-TV broadcast energy are the same as visible light energy, but are said to have different vibratory frequencies.) The temperature of a body emerges from the equilibration of its energy with the energy of other bodies which act as the authoritative radiation source. That is why we said that the enclosure temperature comes from the dominating earth temperature, which comes from the dominating sun temperature. If we
build a fire near the walled enclosure, that will add a dominating component and raise the
temperature of the enclosure. But in all these cases, ultimately the transfer to the enclosure wall
will be electromagnetic radiation. That electromagnetic radiation, absorbed to establish an
equilibrium within the wall, results in the atomisms within the wall (atoms or molecules)
increasing their motional or kinetic energy to an equilibrium value. Thus there is an equivalence
between the electromagnetic radiation temperature of the wall and the kinetic energy of the wall
molecules. It is that energy, whether viewed as coming from the radiation field or from the
kinetic energy of wall molecules - the processes are now equivalent - which establishes the same
kinetic energy of the gas molecules in the enclosure. The same process would take place, if
those gas molecules were replaced by small solid pebbles, living bacterial cells, or human
beings. We would say that from the temperature potential, each of the degrees of mechanical
motional freedom of every atomism in the field receives, shares, and partitions the radiation
energy and exhibits it as kinetic or motional energy. That is where the motional energy came
from. Remember we asked where did the matter come from, where did the motional energy
come from? Now we have told you where the motional energy came from.

But we chose a simple system of point molecules in a gas phase because we can make
clear the most points of exposition. A simple atomism has only three degrees of motional
freedom (not to be confused with density, momentum, energy). It can move in the x, y, z
directions that is, left-right, backward-forward, up-down. These are called independent degrees
of motional freedom; each one is separate from the other. Energetic motion appears partitioned
among these three degrees of motional freedom. That is the basic characteristic of radiation
equilibrium. Each degree of translational freedom, the side-side movements in free space,
becomes full with the same measure of motional energy, which is a measure of the temperature.

So where did the gas molecules get their kinetic energy and momentum? By continuing
to receive impulses from the temperature of the wall. A molecule coming into contact with the
wall is actively kicked by vibration with a wall molecule, or by absorption or emission of
radiating photons. It hits other molecules, etc., and so they 'quickly' establish that motional
equilibrium that we described earlier. For gas molecules the process is fast. For example, under
ordinary conditions on earth, they collide on the average about every tenth of a billionth of a
second. That is why ordinary fluids, gases and liquids made up of molecules, tend to look so
continuous. A glass of water appears to be very continuous almost every way you test it. The
Brownian motion particle collisions in that liquid phase take place so fast and over such small
distances that you cannot easily resolve the motions.

As a second puzzlement, one ought to worry as to how that equipartitioning of energy
among all degrees of freedom, according to temperature, takes place. It is not an obvious
process. As a first homeokinetic principle we have demonstrated that for such equipartitioning
to take place there must be a 'frictional' coupling. You may note in our conservations, the
repeated proviso of no creation or destruction, only transformation. 'Frictional' transformations
are thermodynamic processes in which energy associated with one degree of freedom is
transformed into other degrees of freedom by other than physical mechanical
processes. It is the
existence of such processes that extended Newtonian mechanics. Such frictional transformation
is why we can put so many different kinds of 'body English' on an otherwise elastically
appearing ball. Bounce a spinning ball, it comes off at an angle. Bounce a ball at an angle, it
comes off with a spin. We will, at the end, reveal the ultimate physical source of such
transformation processes. Suffice it to say that thermodynamics will refer to transformations that
occur like temperature transformations. Hammer mechanically on a body and it gets hot. The
transformation of energy was not mechanical. Yet, energy flowed, as we indicated using the radiation field as a carrier. Thus the principle: partitioning of energy among the many degrees of freedom of a system requires frictional, dissipative thermodynamic, coupling. In thermodynamics, this takes the form of the second law of thermodynamics: as a result of natural mechanical processes the order of energy (the entropy is its measure) is lost by frictional dissipative processes. The bouncing ball loses energy, frictionally, each bounce into the wall.

However, note that we did not say the energy is equipartitioned among all degrees of freedom. In the very simple system we used an example, it is the case that energy equipartitioned among the three translational degrees of freedom. Also in simple systems, even if they have more degrees of freedom (for example, internal degrees of atomistic freedom associated with extensions more elaborate than a point mass), there will still be equipartitioning among all degrees of freedom. In fact, whether simple or not, all atomisms will largely equipartition their translational degrees of freedom. In Newtonian mechanics such freedom of motion is identified as center of mass motion, the motion that would ensue if all of the atomistic mass were concentrated at one point, the so-called center of mass of the atomism and it 'translated' its movement 'in three directions.

It is from the partitioning of energy, equipartitioning in proportion to temperature, that the distribution function of the ensemble emerges, the distribution - in the simple case - among density, pressure, and energy. The relation among these three conserved measures, measures conserved at the level of the atomistic interactions, constitutes the 'equation of state' of the ensemble. The equation of state is a real quantitative measure of how the ensemble density, pressure, and energy (or temperature measure) are related. The parsimony of physics states that you do not have to deal with the fantastic number of collisional interactions among the atomistic ensemble players. Instead, an aggregate relation may be expected among those variables and those variables for which conservations exist. If you perform a count of how many interactions are taking place in a gas, you ought to be impressed by the condensation in essential number of relations that have to be followed. Name the type of atomisms, the number density you put into the container, and the container temperature, you get the pressure (the totality of all motional exchanges) that the ensemble can exert.

Confused? Bored? Exhausted? We hope not. The trouble is that if you exhaust at this point, and we have tried to make the story run as quick and simple as we could, then - unfortunately - the alternative you have to turn to becomes another piece of mysticism which doesn't have to deal with such all such complexity. So if you are a jogger, or cobbler, or lawyer, or you manage your home and family, etc., whatever strengths permitted you to go through some skill mastery, use your head. That's what we are trying to force you to do.

We have presented enough of an idea about the equilibrium of our gas ensemble. The cocktail party is at equilibrium. Now we want to examine what happens if there are differences between one part of the ensemble and another. Such differences will make for flow fields.

How do we create differences? It is clear that we can do it many ways. Again they will relate to the conservations.

So to make flow processes that originate from differences clear, we ask that you change the form of the container. Elongate it. Imagine it to be a long tube closed at either end. As long as the entire container shell is closed and of uniform temperature, nothing has changed. The ensemble of gas molecules will have the same uniform properties as before. Those properties do not depend on the shape of the container.
But now let us open the ends of the container, for example, inserting them into large spherical containers. In each of these very large (almost infinite) end containers, we will change the 'end' conditions. For example, we can fill the two with gas molecules of different pressure, but the same temperature; or we can fill the two end containers with gas molecules at the same pressure, but different temperature. Because of the nature of the equation of state, in which pressure, temperature, and density are connected, if we have made these two changes - in temperature and pressure - we have also dealt with the third possible change, end gas containers of say different density but the same temperature, or the same pressure.

What is the effect of different end temperatures or pressures? The effect will be to create a gross movement of the ensemble. Now it will no longer be true that the same number of molecules will be moving in every direction, so that the net movement is zero. Now it is the equivalent of more people crowding in at one end, say under the greater pressure at one end, than are crowding in at the other end, under lesser pressure. Note that the players entering the pipe are new players in all cases. Under the Brownian motion, atomisms from the 'left' end will be working their way at random down to the 'right' end, and conversely. At any local region, the local collisions in the cocktail party will not appear much different than before, except that the individuals being met will much more infrequently be the same individuals that were met when the two ends were closed. But there will be a 'small' net difference in momentum between those moving to the left and those moving to the right. That difference creates the net flow field.

In order to support that 'small' difference in momentum, the flow field, there will be a frictional loss that the source potentials will have to supply. Work will have to be done by the potentials, energy will be degraded in order. The measures of those degradations are known as transport coefficients or diffusions (or in reciprocal form, of resistances). Once more stressing the parsimony of the construct, there will be frictional diffusions corresponding to each conservation. For example: if we were watching one kind of atomism dragging through, by changing concentration, another kind of atomism, the diffusion measure would be the mass diffusivity. An experiment? Drop some red dye in a liquid, and watch the diffusion of red dye molecules among liquid molecules.

Or, if we were watching the diffusion of movement (momentum) in an ensemble, the measure would be the momentum diffusivity (called the fluid viscosity). An experiment? Move a stick up and down in a pool of water, or stir a cup of coffee with a spoon, and watch how the motion diffuses. One moving layer of fluid drags on the next. This occurs because the moving molecules in one layer move into the other.

Or, if we were watching the diffusion of energy (or its temperature measure), the measure would be the energy diffusivity (called the heat conductivity). An experiment? Pour some hot fluid into a body of cold fluid and either feel (with a finger or with a thermometer) and watch the heat or temperature diffuse. Again, the more energetic molecules in the one body move into the second.

So we see how differences in the two end containers, acting as potentials, can create flow fields that may exhibit one or more of these transports. That is, create a difference in concentration between the end containers or a difference in pressure, or a difference in temperature and watch a flow field develop.

Note that if the transport goes on long enough, to where the potentials of the two end containers equalize (say both ends finally reach the same pressure and temperature, and density), then the transport flow ceases. Once more we have an equilibrium. So, flow fields are maintained by potential differences.
Actually, even though there was a flow field, locally in every region of the flow field, the local variables of pressure, temperature, density were nearly at equilibrium and expressible by an equation of state. It is just that the state from region to region (not the equation of state) differed a little. We would say that the variables has a difference or gradient (slope). Thus in flow fields, we note that we have ‘doubled’ the number of descriptive variables. There are the rest state variables: pressure, temperature, density; and there are the transport state variables: the gradient (or rate of change) of pressure, of temperature, of density, and the gradient of movement, the velocity. What physics does, when applied to ensembles, is it describes the rest state (by thermostatics) and the changing state (by thermodynamics). While the formal subject has the name thermodynamics, the thermo part does not only refer to heat or temperature, but to flow and equilibrium among all sources and avenues of energy storage and exchange. But the conservations that we deal with are not just energy. They are mass, momentum, and energy.

In all such flow fields, remarkably enough, we can classify all dynamic processes taking place in the field, regardless of the type of potential or conservation, by three general processes. Again these are not related to the three simple conservations. The most general processes within any field are two locally - diffusion and coherent wave propagation; and throughout the field at a larger scale, convection. All diffusion results from 'random walk' processes; gradient diffusion results from such processes, in net differential form, in which more atomisms from the more endowed region move into the less endowed simply because of the difference in endowment. In coherent wave propagation, atomisms march in as a coherent file, one carrying the message to the next, like beads colliding on a string. In convection, the entire local group is replaced by a new group moving in as replacement. These three kinds of processes are the only kinds that can exist. They include electromagnetic radiation among them as a special form of wave propagation.

This is an introduction to fluid mechanics, or thermodynamics. Here we introduced it for our simple gas molecules. We cannot continue to discuss all of the extensive physical science and technology that is associated with this subject. That would be a textbook in, say, hydrodynamics. Suffice it to say that such fluid mechanics (or hydrodynamics) makes the flow of water in your plumbing, the washing and drying of your clothes, the cooking of your food, the ocean and the atmosphere around you, even the flow of blood in your arteries, and the electrical and chemical flows in your nerves. It also makes up the processes in stars and galaxies that support your existence. It is a remarkable course of study, but we cannot pursue it here in detail.

However, so that you do not confine your thinking to a 'flatland' physics of one level of organization, we will introduce a primitive form of a new theme.

Note that when the potentials equalized, that the atomisms come to equilibrium among their basic conservations. Thus the rest or equilibrium state.

Suppose, instead, we maintained a small gradient, e.g., a difference in pressure of the ends of a pipe. Then a steady state flow field could be maintained by that difference in potential. We wish to discuss the form of that flow field. Its measures will depend on the diffusivities. If the gradient differences are relaxed, the field relaxes to rest. Only a uniform diffusion continues on.

However, at small gradient differences, the flow field is very smooth and regular. It is known as a laminar (smooth, sheet-like) flow field. Only two processes are found in the field-gradient diffusion and wave propagation. The field is said to be mathematically linear. Double any gradient and the field velocity doubles. The mathematical relationship is graphed as a straight line. Convection is a nonlinear field process. It depends on the field velocity sweeping
new gradients into place. Thus its measure is a product measure. Double the velocity, the convection increases four-fold (two times two), nonlinearly. Thus, while in the laminar flow regime, the velocity effects are linear because the convection is negligible, a critical value of field velocity is reached and suddenly, precipitously, the form of the velocity field changes. It becomes turbulent, eddying. (What are eddies? Watch a fast flow field, you will see the swirls, eddies, vortices. A tornado is a very big form of such an eddy. Bathtubs show smaller forms on draining. Your teaspoon in a teacup shows even smaller forms. Or, there are eddying vortexes shed from your oar as you dip it into the water and stroke with the oar.)

That sudden transition from a laminar to a turbulent flow field is a problem in mathematical-physical stability. It makes for some of the most interesting, and important processes in nature. In fact, much of nature is organized by the appearance of such dynamic forms.

Yet even though these changed forms exist, the local equation of state among the atomisms remain basically unchanged, near equilibrium. It is just that more graininess, more chunkiness, has emerged in the field.

One more point, when such process changes take place 'internally,' not just as an evanescent flow form appearing among the point atomisms, but if they actually create forms with some extension, and additional degrees of freedom, then those new forms exist as higher organization. This process is a different kind of flow process. It is internalized. It is known as the process of matter condensation, or condensation. It is from some such locking together, a binding of atomisms, into higher condensed forms that a hierarchy of forms emerges in nature. But that is our subsequent theme.
Chapter Three: A Bacterial Colony - A Model for Living Systems

Here we shall plunge into considering one of the simplest of complex systems, one of the simplest forms of living systems. By taking this step, we have shown our immediate willingness and readiness to take physics up to living systems. But, by the very choice, we can show experts on both sides of the conceptual intellectual fence, both physicists and chemists, and biologists that we are talking physics.

Note that in our simple system of point atomisms, we had to deal only with three conservations. Suppose we had simple atomisms that weren't points. A typical case are ordinary atoms and molecules. They already represent condensed matter systems. In their bodies, they bind their elementary parts and form solar system-like atomic or molecular shapes. These shapes, unless the collisions are very jolting, are preserved during collisions within the ensemble. But now their atomistic motion exhibits more degrees of freedom. The internal parts may spin, they may vibrate, they may even change their association among partners. Each of these degrees of internal freedom in an atomism can absorb energy.

Now if or when such atomisms are only simple systems, the kinetic or motional energy is equipartitioned among every such degree of freedom, whether internal or external (the movement of translation). That is the definition of simple systems. When simple systems bang into each other, that energy is shared by every moving part.

Do any such simple systems exist? Yes, simple helium atoms, or oxygen or hydrogen or water molecules interacting in a gas-like phase at remote separation behave like simple atomisms. A loose description is that their internal degrees of freedom seem to act like perfect little springs, quickly sharing and partitioning the collisional energy per external collision. Thus a thermodynamic description recognizes that they can absorb more energy internally than the simple point atomism (their specific heat is said to be higher), yet their thermodynamic description will still only relate to the three centers of mass conservations - mass, momentum, energy. Why? Because each momentum collision will quickly partition energy among internal degrees of freedom, but the center of mass motion of the atomism as a point atomism will not be affected. Each particle acts as the leader for all of its parts. Newton was the one who basically figured that notion out, for any ensemble, before anyone figured out how to treat the thermodynamic partitioning of energy. Remember we said that there really is a frictional coupling for all such processes, but in simple atomisms that process is hidden and so we will not stir it up here.

But now suppose there is more complexity to the motion than for simple atomisms. What might complexity refer to? It refers to time delayed or exchanging actions within the interior of a more complex atomism. From where do such processes arise? They arise because the internal elements and their degrees of freedom are not spring-like. Instead, they themselves contribute fluid-like, gel (like gelatin) as well as solid-like and elastic-like field forms and processes. How can that be? Simple. The atomisms themselves are 'condensed matter.' They are made up of smaller atomisms, comprising in toto a field. Their very remarkable property, which we shall not document and discuss here, is that the process takes place by self-organization.

The existence of complex atomisms is itself a measure of the existence of a hierarchy of systems. Hierarchy, in an ecclesiastic and secular sense derives from the notion of a flow of authority, an ordering by the flow of authority. We use it in precisely that sense. The atomism has authority over its lower level of subatomisms. Authority exerted from above is sufficient to cause self-organization of systems.
But if those lower ordered level of atomisms delay their actions much longer than the
time between atomistic collisions, then their time scale of delay governs the atomistic process,
not the atomistic process of collisions.

Example? You bump into me. If we were simple atomisms like two billiard balls, the
entire exchange would be just a momentum and energy exchange into our respective degrees of
internal freedom. But you and I have a brain and nervous system, and cells. They start an entire
communicational and flow process. "What did he mean by that?", they may ask. A long time
delay of internal processes take place before the result of what appears to be a simple collision is
over. Such internal delayed response is what determines the internal component of pressure that
we believe represents the social pressure in complex ensembles.

Physics, heretofore, has not taken into full account the internal relaxation process,
particularly since it can seem to split 'freely' into translational movement or into condensed
matter movements, e.g., I may form a chemical memory of that collision. We have shown that
such branching has always been an intrinsic component of physics, at least as definite as the
diffusive transport of shear viscosity, whereby movement or momentum is transported from one
ensemble region to another. (Remember how we stirred up a cup of tea.) There is a second
diffusive measure. It is called the bulk (or volume) viscosity. It measures transport from region
to region into the internal degrees of freedom of the atomisms in the ensemble.

To make the notion clear, regard the atomism more properly to be a factory. It has a
factory day. That is the time that the interior of the atomism processes all matter, momentum,
ergy required to maintain its own form and function. You are such an atomism, so is a cell, a
society, a star, etc.

Complexity thus arises when the internal factory day of the atomism is much longer than
the time between atomistic collisions. Thus, for example, you do not have to receive energy
'continuously' collision by collision. You can eat (take aboard energy) a few times a day, store it,
convert it as needed, yet use it 'continuously' internally.

But complex processes can exhibit two different kinds of characteristics. The simpler
kind is chemical change. Parts of atoms may be exchanged. Chemistry, regardless of the
atomistic level of organization, may be defined as the making, breaking, or exchanging of
bonded or bonding fragments. Those exchanges begin to have a time scale, determined by
reaction rates for the making, breaking, or exchanging of parts. Physics, when it encounters
chemical change, in ensembles (i.e., more than one kind of atomistic player present), proceeds to
increase its count of conservations, one for each 'equilibrium' player. Often such chemical
games may only be a transient game in which the initial players are transformed into other final
players. Pour some lemon juice over a spoonful of bicarbonate for an antidote for that upset
stomach (cocktail party?) and you have such a reaction. That most often is the more limited
chemical game.

But more complex games will involve the continued persistence of major atomistic
players. When we come to the living system, it is that sort of chemistry we are interested in.
Our chemical forms are themselves 'factories,' continuously making, breaking, and exchanging
bonded material.

For the sake of this chapter and what comes beyond, we want to tell about how two basic
conservations are transformed.

First, for all complex systems, ones in which the factory day of the process (internally, or
exchanging) is long compared to the translational collision time, it is useless to discuss such
systems in terms of the translational or external movement (momentum) variable. That relates to the collision time scale. Instead we have to relate to the factory equilibrium scale of time.

The basic question is what is the physics of the factory, how is it exhibited? That relates to the kinds of sustained diffusional processes (flow processes) that go on inside the factory. For good physical reasons, we refer to these organized actions as modes, or action modes. Action, we can now tell you, is the product of energy and time. It measures how much energy a system puts into transit and the time over which that energy is put into transit while it is doing something, a particular labeled action. The activity budget is how people apportion their energy over their near equilibrium factory day. People eat, sleep, work, sex, attend to each other, etc., perhaps twenty actions in all. A meteorological air mass movement over a continent exhibits its matrix or ring of modes, etc. A factory day is defined by that entire cycle or ring of modes which brings the system back to an indistinguishable 'starting' point. Obviously, most modes, in the human are discharged in a day. For the species, the generation time is closer to the factory day. For a galaxy, the time scale of its whirl (e.g., 100 million years) may nearly define its day.

Simple systems only conserve their matter and their motional energy and movement throughout their collisions; complex systems, in addition, support the motions or actions of their internal parts. These actions are conserved as a cycle, a ring, or a matrix of action modes.

But there are many complex systems that are not living. In this chapter we promised to tell you about living systems. So we must get on to one new conservation.

But first, how do you know a living system? Because of the factory complexity of their interiors, living systems furnish most people with their central idea of what a complex system is like. But of course, there are many other complex systems. It only takes inside moving parts that need be supplied to have a complex system. Oceans of water and air, stars, atoms, molecules, all have such moving parts.

The basic process we see in living systems is that their form is not forever. Instead living systems reproduce living systems. Once again, as in demonstrating that physics could deal with complex as well as simple systems by recognizing the new conservation of internal action modes, we must make clear that our old conservations (four - for now we have added the ring of action modes) are not changed. Instead, perhaps, a new conservation is added.

Now reproduction of 'self' is not a process unique to what we all tend to call 'living' systems. The very act of 'reproducing' the action matrix has that character. Wave propagative processes have that character. Weather begets weather, ocean wave begets ocean wave, etc. But there is an even more extended form of the process. Perhaps you do not know, but stellar processes beget stellar processes, star begets star. Unfortunately that process has only taken place for two generations. A first generation of stars made matter and led to the current generation of stars. Is this sufficient to raise the question of a new conservation?

No. In the living system, each generation begets a new generation. That physical process is not the characteristic of an individual, although it is the individual atomism that reproduces (by growth and division, or by sexual conjugation, whereby one or two similar but not identical atomisms 'conceive' and prepare a new atomism for growth and separation). It is by the fact that interaction by interaction, generation by generation, the members of an ensemble of atomisms, now called a biological or living species, that reproduction of number takes place. Thus, it is now conceivable and proper to speak of number, population number, demography of a species, as a new conservation.

In living species, in addition to other conservations, population number is conserved; generation begets generation.
Some explanation is necessary of this principle. Conservations are observed when equilibrium situations are arrived at. But commonly we do not see or work with ensembles at perfect equilibrium, only near equilibrium. The idea of a conservation is not thereby destroyed. Instead it has to be used carefully with understanding. Thus in a simple or complex system, when we speak of the conservations of mass, momentum, and energy, this does not mean that they are not changing in the ensemble. If we pack more atoms or people into an enclosure, by virtue of their compressibility, we cannot say mass is conserved for the total ensemble in the container. It is only that in their collisions, we do not (or very very seldom) lose matter. (In the next chapter, we indicate that very hard collisions can transform matter into energy.) If momentum is lost or gained in an ensemble, it is because it is put in or taken out of the boundaries or gates to the ensemble. The same for energy.

Population number is a physical process that wells up out of the interior of atomisms. Thus in the ensemble, it need not be perfectly conserved. The basic notion is that if the species, as a system persists, reproduction must reliably well up out of the interior. The interior is the gate to ensemble number. Thus, for a short run, we can describe ensemble motion without attending to population number. How people interact in a city, or animals in a forest, can be described without discussing the population equilibrium. But if the physics is to be complete, if one is to know how the process runs autonomously, from its driving potentials, then you cannot deal with the level of individuals and their fluctuations (after all, they may act as if they have 'free will,' as does almost every other atomism for its individual action fluctuations). You must average over the factory day, the generation, in fact over a number of generations. After three generations, the individual fluctuations relax more into place. (What was it that Andy Jackson did, or Teddy Roosevelt? Who was Delores del Rio, or Eddie Cantor? Do the newer generations recognize these older human fluctuations?)

Also, we have to note that the conservation of mass and of number are different, independent. For systems that do not live and die, or grow and reproduce, number and mass come up with directly and strictly proportional measures. Each mass unit contributes a number unit. Once growth and division take place, mass and number are separated. They fluctuate independently. You can take on food and grow and grow (some adults weigh 90 pounds, others 300 pounds); this is different from dividing and reproducing. The problem we face in physics, again and again, is how does the balance - at equilibrium, or in flow processes - take place among the various conservational compartments for the ensemble.

So now, with this long introduction over, we shall show that there really is such a physics for a living species. For clarity, we have taken a simple species. But we must add one more note.

What are the potentials off which a living species operates? Clearly, as for all other atomisms, including simple atomisms, the living systems operate off a temperature potential. That potential has to be found in a much narrower range than for other atomisms. The range, largely is the range for liquid water. Why? Because life, the interior of each atomistic organism, basically depends on water and its liquid state. Thus 0°C (32°F) to 100°C (212°F) is the total useful range. But since, in addition to water, life uses a few other chemicals - oils and fats, simple and complex sugars (carbohydrates), and protein fragments (peptides) and proteins - the limitations are a little more severe. Specifically, since you know eggs hard boil easily, because of a prime protein that they contain, albumin, as a foodstuff to make and feed unborn chickens, you may suspect that the hardening of protein takes place at less than boiling water (100°C) temperature. True. It hardens by about 70°C (about 158°F). Do not expect to live long if you
are completely immersed below 32°F or above 158°F for extended periods of time. You freeze or 'get cooked.'

If atomistic living systems are to support their internal forms, mechanisms, and processes, they use both stores of material for replacement of turnover, and they need energetics to run their internal reactions. Thus there must be two additional potentials - the chemical potential of required atomic or molecular species that are required for building materials or for functional performance and the chemical potential that supplies energy. There are some species, photosynthetic species (e.g., those that can make chlorophyll from atomic constituents in the atmosphere and from sunlight), that can use the solar radiation directly for their energy source. All other species require the presence of such more primitive species to build up all the required chemical potentials. They live in an ecological web consisting of a number of trophic levels (levels of who eats whom). So in general, we have to face need for two such classes of potentials, the chemical potentials of required mass species, and the 'free energy' chemical potential for energy.

But reproduction cannot simply be 'willed' by the individual. It requires a very special potential, the genetic potential, which is a very specialized form of chemical potential that is carried aboard the organism. All viable living system share a germ cell (single celled animals are their own germ cells; multicellular animals have a store of germ cells). Within such cells, there are gene bodies, arranged in chromosomes, each made up of chemical beaded fibers, DNA, that carry the reproductive machinery and action capability. The story is complex, and is described at least once a week or month in newspapers, magazines, books. It is part of the detailed story of molecular biology. The important generalization now a physical point of view, is that in living systems, there exists an on-board chemical potential, the genetic code, by which the process of reproduction is initiated, generation by generation, to develop the conservation of population number. Boy meets girl, boy loses girl, boy 'gets' girl, a new boy or girl is born! There. That wasn't any fantastic extension of the formula.

And of course, being a complex atomism, a reliable repertoire of action modes, emergent from the genetic code, has to exist. How a coded sequence leads to action modes is only now in process of deciphering. It is beginning to be understood at the virus and the bacterial level of living forms or forms associated with life.

So now we can get on with our colony of bacteria. We will exhibit the physics, at equilibrium, as a flow process. The advantage is that you will clearly see the role of each potential, and of each conservation, which we shall refer to as flux (or flow) conservations.

First - what are the action modes of a bacterium? (If we were discussing humans, you know them. If you have experience raising cats, or dogs, or cows, or sheep, or wheat, or corn, or weeds, you have a fair idea about them. If you will spend some time gazing at stars, or flow fields, or weather, or oceans, you will get to know their action modes.) Quickly stated, bacteria (at least simple ciliated bacteria, who move by rotating their cilia or tails) grow - divide - move in a straight line - tumble - digest - metabolize - excrete - die. Some of these processes are serial some occur in parallel (at the same time). Their motion alternates between straight line movements and brief tumbles. If the chemical environment is favorable, they swim longer straight lines.

With this information, can we design a system that will keep a single 'species' of bacteria going 'forever'? And does that maintenance fit in with our physical prescription for operation? Note that it did, in fact, when we developed it around the motion of atoms in an enclosure and used motion at a cocktail party to enrich the metaphor.
In order to design a system involving complex atomisms, we must first (always) make use of the existence of a ring of action modes and our knowledge of those modes for command-control. It is how we can assert our 'authority' from above. We will use the move and tumble translational motion to herd the bacteria.

So imagine a flow of water descending in a glass pipe at some very slow rate. Why? So that we can make the bacteria appear, as a passing parade, in a historical process. We can imagine dripping water into the pipe at a slow rate and letting it run out somewhere else, by controlling the flow to maintain the position of a surface. The velocity of water should suit bacterial movement. Our intent is to keep live ones (those that are metabolizing and moving) near that surface, and any that die should be swept away. That is, we are controlling the flow field to shepherd our flock. (It would be like putting grazing cows on a controlled turntable.)

Oh yes, turn on a proper temperature for the walls. Bacteria have a preferred temperature range that controls their division rate. If, too cold, they divide and double their number very sluggishly; if too hot, they stop; if fairly warm and just right, they divide commonly as frequently as every twenty minutes. Twenty minutes is their generation time.

Why should they swim where we want them to? If all we furnish is water, then they will disperse and diffuse to every part of the watery flow field they can reach. We have not supplied all the potentials to permit them to satisfy their conservations.

So add 'nutrients,' the two missing potentials - the chemical potentials of required molecular species, and the chemical potential of free energy.

Complex systems operate their conservations at the most organized level they are designed to handle. For living systems, this means that 'chemistry' is not conducted at nuclear particle, atomic particle levels, but at levels of higher molecular organization. This consists of fat fragments (lipids), protein fragments (peptides, or their constituent amino acids), carbohydrate fragments (simpler sugars), a variety of ionic constituents, e.g. sodium, potassium, calcium, sulfur, iron, magnesium, chloride, carbonate.

So for the particular bacterium we may choose to raise, we have to design a fairly careful supply of chemical and energy potentials. It doesn't have to be a perfect design, some materials will be in excess. But there likely may be one or more materials that are critical and 'rate governing.' Their amount will just correspond to the division rate and growth that will be maintained. So now add these potentials as a continued flow rate, by adjusting the concentrations of the constituents, in the water stream.

Now we have forced the action modes of the ensemble. Now we have herded them without a sheep dog. Why? Those that swim near the surface find the maximum concentration of nutrient. Those that swim behind find the stores depleted. The rule for the motional action mode is to swim longer where or when the nutrients are favorable. Thus the bacteria cluster as a cloud near the surface.

Once again we have shown how a random diffusive motion in a uniform field results in a directed motion by a gradient or difference in potential. Yet the atomisms do not know the difference. There is no question of free will aboard to change the apparently different form of motion. (People are diffused in a field in a park on a summer day; someone yells "Food!" or some other attention-getting signal is sounded out. The people cluster. In both cases, they were attending to their command-control cognitions in their sensory - perception - motor brain space.)

Now that the flow field is set up, we can introduce the species we are interested in herding, and watch the physical process that develops toward equilibrium. Since the atomistic species is living, we can start their number with one. Put one bacterium into the field. After a
'collisional' cycle for a complex system, the factory day of one generation, twenty minutes, there will be two, and then four, etc. The number will grow up until equilibrium. What is that equilibrium? It depends on particular species.

We will imagine a common case of a species that dies after a number of divisions. Then one possible kind of process will be a division rate in which the number of bacteria that are produced anew is equal to the number that die and are swept away. That provides a strict equilibrium in number. Under those conditions, we understand the need for each of the supply potentials. The chemical potentials of materials are supplied to replace the materials carried off by dead bacteria (i.e., thus their equilibrium number), and the free energy potential (that is its rate) is independently provided to supply the average metabolism of the growing and actively swimming cohort of live bacteria at their equilibrium number.

Clearly every potential was needed, every flux compartment was essential. Action modes, mass species, energy, population numbers were involved all at equilibrium. We do not have to go on to all the transient or changing problems that can be imagined. Loosely we can view many of them as the question of what happens when a colony of bacteria is transferred from one environment to another. How does the movement toward equilibrium then take place? That would constitute the dynamic equations of change, and would involve various kinds of diffusive transport (of momentum, of energy, of population number, of action modes).

Of course, all bacteria do not behave in that simple way of dying so conveniently and regularly. Many types, particularly if run with some sufficiently high density so that they chemically interact with each other, may exhibit other behavior, which originates from their interactive modes. Many bacteria may put out an excretory chemical signal that will inhibit other neighboring bacterial from dividing. Their mutual interaction may thus slow down their division rate. Or, by virtue of such constituents in the environment, death may also emerge. There may then arise a cycling process in the ensemble, in which rapid growth periods alternate with slowing growth periods and death. And so on. More than one form of dynamics may arise, depending on how processes are coupled together, yet the number of basic conservations would still remain the few named.

Systems of interactive atomisms, even if living atomisms, operate by means of very few conservations.
There was a time, not very long ago, when the story or history of stars were forever. The Greeks pictured them fastened to a great crystalline sphere in the heavens that rotated as a whole, perfect, immutable. On the other hand, 'short term' stories of creation, of gods, or one God, began to make their appearance in recorded history - recorded by the Sumerians, the Egyptians, the Hebrews, the Christians. Beginnings of history of the universe, as furnished by these stories, had time scales in the thousands of years. Which was true - a universe that had lasted forever, or thousands of years? Those stories changed only in the 20th Century, although - interestingly enough - it was geologist and biologist, Lyell and Darwin, who began to raise the question most seriously and persistently in the 19th Century. A process typology in geological formation, their possible rates and dating, the discovery of fossils and the diversity of the biological record as a historic and evolutionary record, began to suggest process time scales in the billions of years. (Eiseley's Darwin's Century tells a great deal of the story very engagingly). Untangling the biological problem, the basis for so much diversity in living forms, which we shall not discuss here, was to change the view of evolution as a movement, under God's rule, of biological species to perfection, acting for the elimination of the unfit (or a completely unchanging succession of life forms, a notion that the fossil record itself began to dispute), toward Darwin's notion of a 'pressure' for natural selection. The mode through which such 'pressure' might act, by selection of the chemical changes brought about by material-physical mutation of a genetic code (of actual changes in coding in molecules - the DNA-RNA dual coding and reproductive expression), was not yet available conceptually, but the notion of a coded carrier began to appear on the intellectual horizon. The slowness of such processes, for species, families, phyla, even biological kingdoms, also put the biological time scale in accord with the geological time scale. (As for example, the ultimate assignment of all complex life form to the Cambrian Age of the past ½ billion years, or the more recent assignment of 4 billion years to the start up of life.)

The Newtonian revolution, and the physics and chemistry, and thermodynamics, of real bodies, including the sun, and planets, and atoms, forced the question of what was the sun, and how could it act as a source of energy for the necessary time scales. Clearly, with energy being finite and conserved, the sun could no longer have lasted forever. On the other hand, since it obviously was responsible for maintaining earth's processes, its life too had to be measured in billions of years.

Thus one more system appeared on the agenda that had an apparent common property with other systems. Ultimately one sees, from thermodynamic considerations, that all systems have a birth, a life span, and a degradation phase, even the sun.

It was also realized that the sun is 'just' a star, like other stars that appear in the heavens, apparently 'immutably' appearing because of the earth's rotation about its axis, and their relative fixity among each other. (The many more detailed motions - of the earth's revolution around the sun, the wobbling or rotation of its axis, etc. - have been the subject of very detailed astronomical study, by the laws of physics, ever since Newton.)

But more immediately, returning to the sun, a process life scale for the sun had to be found. No source of chemical free energy potential, or physical potential such as gravity could be found that could account for long life beyond the tens of millions of years - until the discovery of radioactivity in 1903. It was then realized, for the first time, that a source of energy, energy bound within the very core of the atom, not its simpler chemical binding, of tremendous magnitude could be found at least in certain atomic elements.
But that was just the opening of the atomic age. Note that at the same time, physics learned the secrets of the small - the atomic constituents of matter - and of the large - how stars, galaxies, and the cosmos itself works. We will not tell that story. It can be read about, most entertainingly in George Gamow's many popular books. (They are in paperback. You will read them with great joy and pleasure.)

But, quickly the foundation of chemical processes at the atomic level was developed (roughly speaking, by the end of World War I). The atom consisted of an electrified nuclear core, surrounded by a solar system of orbiting electrons of opposite electrical sign; the electrons were bound to the nucleus by electrical attraction. How about the force of gravity? It exists, but at these small sizes of mass, the gravity force was negligible (and thus neglectable).

Ordinary atomic and molecular chemistry developed from how such atoms might lose some of their electrons, becoming ions (solar systems with some net electrical change) or how such neutral atoms or electrified ions might interpenetrate in their orbits and form molecules. (Much drier than Gamow, Pauling's The Architecture of Molecules presents the most beautiful pictorial representation of molecules.) That chemistry consisted of the making, breaking, and exchanging of such electrical bonds. Two basic kinds of electrical bonds were found, one a 'static' bond between oppositely signed (plus or minus - opposite signs attract) electrical charges; the other a 'dynamic' bond in which light electrons run around and 'service' more than one heavier nucleus (boys and girls arranged in menage a trois?). The first are known as electrostatic or ionic bonds, the second as exchange bonds. Salt, for example, is an ionic bond between a sodium atom and a chlorine atom. Molecular hydrogen is an exchange bond between two hydrogen atoms. The ordinary chemistry of combustion relates to these atoms. 'Burn' hydrogen with oxygen and you get almost as energetic a chemical reaction as you can get.

But nuclear chemistry involves much stronger bonding and much greater energies. The energy releases when atomic nuclei are disrupted. Radioactivity, natural radioactivity discovered when the atomic element radium was purified and separated in sufficient extent, was the first example of the process that was formally identified, and from which the fantastic energies involved in the binding were appreciated.

What is the source of the fantastic energy? It is the fact, as Einstein established, that there actually is a very hidden connection between mass and energy, \( E = mc^2 \). There is nothing in the principles that we have spoken about to anticipate this result. It arises from the basic question we asked and didn't answer; what is matter. Again, we promise to tell more about that problem later. Suffice it to say, now, that if the binding energies among nuclear constituents can be released, very large amounts of energy can be obtained. It is such transformations that run stars. Very few processes on earth partake in any significant way in such processes.

So what is a nucleus made up of, and what are the binding processes involved in making, breaking, or exchanging such bonds (nuclear chemistry)?

While at first, nuclei were thought to be made up of particles with opposite charged signs to electrons, protons, it was soon realized that a second particle, the electrically neutral neutron also existed. The problem was how could a group of like (positively) charged particles bind together, instead of repelling each other and blowing apart? The answer is now known to be some very close exchange process among neutrons and protons. That binding process is said to involve a third one of the four known force systems of physics, the strong nuclear force. It is suspected that perhaps a very special exchange character of the electrodynamic force system may in fact be responsible for the strong nuclear force, but tentatively it may still be regarded as independent even if (or when) the electrodynamic origins are established.
Without going too far into atomic physics, we can illustrate some of the rudimentary issues. The stable line of atomic structure in the table of elements developed by Mendeleev, which pointed up the location and thus helped predict any elements about which knowledge was missing (such as radium) starts as follows in terms of increasing mass \((p = \text{proton (positive)}, n = \text{neutron (neutral)}, e = \text{electron (negative)})\).

<table>
<thead>
<tr>
<th>element name</th>
<th>nucleus</th>
<th>outer orbital electrons</th>
<th>relative atomic weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydrogen</td>
<td>1p</td>
<td>1e</td>
<td>1</td>
</tr>
<tr>
<td>(deuterium)</td>
<td>1p + 1n</td>
<td>1e</td>
<td>2</td>
</tr>
<tr>
<td>helium</td>
<td>2p + 2n</td>
<td>2e</td>
<td>4</td>
</tr>
<tr>
<td>lithium</td>
<td>3p + 3n</td>
<td>3e</td>
<td>6</td>
</tr>
<tr>
<td>beryllium</td>
<td>4p + 4n</td>
<td>4e</td>
<td>9</td>
</tr>
<tr>
<td>boron</td>
<td>5p + 5n</td>
<td>5e</td>
<td>10</td>
</tr>
<tr>
<td>carbon</td>
<td>6p + 6n</td>
<td>6e</td>
<td>12</td>
</tr>
<tr>
<td>nitrogen</td>
<td>7p + 7n</td>
<td>7e</td>
<td>14</td>
</tr>
<tr>
<td>oxygen</td>
<td>8p + 8n</td>
<td>8e</td>
<td>16</td>
</tr>
</tbody>
</table>

One sees approximately equal numbers of protons and neutrons in the nucleus; but at larger atomic weights stability generally requires a growing excess of neutrons above protons. Uranium, for example, atomic number 92 (92 electrons), has \(92p + 143n\).

But from our point of view, we are interested in the 'mass defect,' how much the nucleus 'weighs,' actually its apparent mass, relative to how its protons and neutrons would weigh if independently weighed. The important thing, for most stellar processes, is the mass defect of helium (four hydrogens would weigh 4.032; helium weighs 4.004. The difference is 0.028 for four particles, or 0.007 per particle. By Einstein's formula, \(E = mc^2\), that 'small' mass difference makes a very large amount of energy, enough to run the sun for billions of years). The basic process that energizes stars is the nuclear 'burning' of hydrogen to helium. What that means is that when hydrogen nuclei collide (in stars, there are no atoms, the electrons are stripped off; the energies involved are so high that the 'penny ante' electron players cannot compete with the 'high rolling' nuclear players - less picturesquely, the nuclear force is so much greater than the electrical force on electrons), and bind to form helium nuclei (four hydrogens form one helium), the binding energy given up is so greater that it energizes the sun. **Bonding requires giving up of energy.**

How is that energy measured? Again by temperature. There is nothing in our previous gas process that a boost of the container temperature to 10,000,000°C wouldn't exhibit. So, as the temperature, or the motional energy of atomisms get up above a million °C, the nuclear core of atoms are sufficiently battered that they begin to exhibit and release fantastic internal energies, if you will energy tied up within their fantastic internal 'springiness.'

Natural radioactivity at any low temperature is a spontaneous process by which large unstable nuclei crack themselves open, split into fragments and release energy. Once upon a time all of these elements were made (a story reserved for later) in a first generation of stellar processes.

But the story we must now tell is the story of how the main sequence of most modern stars work, of which our sun is one. Their dominant characteristics? They basically burn
hydrogen (protons) into helium (2p + 2n combinations) at temperatures about 10 million °C. The main line of stars range in mass, roughly from 1/10th of our sun's mass, to 30 times our sun's mass. Their life depends largely on that size. The small ones burn out in a million years; our sun will likely have a life of about ten billion years (it is in 'middle' age now); the small ones have lives up to one hundred billion years.

We start from hydrogen gas in the spiral arms of many spinning galaxies. Gravity acts to pull gas together and gravitational shock waves tend to create a high temperature front passing through the spiral arms. Even though the gas is very tenuous, like the apparent vacuum in space between stars, motional or kinetic temperatures reach a million °C. The nuclear fires start. What does that mean?

It means gravity pulls the protons together (as a large mass ensemble of such protons), and they begin to rush about very speedily and collide with each other. 'Before' they were moving more or less coherently, with little interaction; 'after' they are involved in a boxed together cluster involving wild impingement upon each other. Gravity binds them without an enclosure as we pictured before. The dual force systems, however, are required - gravitational force, and the mechanical centrifugal force developed by rotation. What gave the galaxy its rotational energy? Don't ask that now. We will tell you a little about that later. Suffice it to say that two force systems helped bring about conditions under which stars would start.

What are the conservations in the collision among particles, even though the colliding particles are nuclear fragments, and a chemistry of making, breaking, and exchanging of bonds is involved. They are essentially the same as before -mass species, momenta, energy. Since the atomisms, the nuclear particles are complex, that is they have an internal structure that is involved in energy partitioning, then they act also to conserve their internal action modes.

For the nuclear particles, those action modes are simple nuclear chemical processes. Generally, in such a case, we would identify the chemical 'reaction.' In its simplest form, we would say that the constituents are 'burning' to produce a constant release of nuclear energy (from the mass defect conversion) per unit mass of star per unit of time.

A nice introduction, admittedly with mathematics involved, is given by Schwarzschild Structure and Evolution of The Stars. (Meaning can be followed there, loosely, without paying attention to the mathematics.) The essential ideas are the following:

1. The same equation of state holds for the gas particles in our balloon as it does for the nuclear particles in a star. (Why? Because they are both gases, with the particles far apart compared to their individual sizes or extent.)

2. The conservation of mass tells you how much matter there is in any spherical interior to the star in terms of density (one of the parameters in the equation of state).

3. Since that matter is acted upon by a radial pull toward the center of the star (the same reason that objects are pulled toward the center of the earth when you let go of them), due to gravity, that force creates a radial pressure gradient within the star. (The same reason that the pile up of gas molecules, under the pull of gravity, in the atmosphere creates an atmospheric gas pressure on earth, or the pile up of water molecules in the ocean creates very high pressure at the bottom of the ocean.) That pressure is another of the parameters in the equation of state.

4. There are three kinds of energy to be balanced in the star: the thermal energy that is represented by the high collisional energy of motion (kinetic energy); the gravitational energy that results from the gravitational force that holds these particles together (for example, one measures the force conceptually, by what it would take to pull a particle away from the star); the rate at which energy is created by nuclear reactions.
The two energies - thermal and gravitational - are essentially equal. It is that fact which really poses the older 19th Century problem.

Let us suppose that these were the only two energy storages available to us. Then what we would see is that the pull of gravity (like a tightly wound ball of rubber bands from which elastic energy was being taken out in the middle) would cause the star to contract. Why? Because thermal energy is being radiated away from the surface of the star. That gravitational pull is what keeps the star warm. The ratio of the gravitational energy available to the rate at which energy is being radiated away, for our sun, is about 30 million years, the estimate that Lord Kelvin made in the 19th Century, when he could see no other mechanism for supporting the sun. But now 'burn' the hydrogen to helium, by virtue of its mass defect, and by virtue of using the gravitational force to put the vigorous squeeze on the nuclear particles, it can now support both the heated up star mass and the rate of energy (power) that the star loses for billions of years. That is all there is to the basic process in the star.

Of course there are many more details of great interest to physicists. The fact that most stars run by burning hydrogen to helium doesn't prevent other nuclear reactions. When that reaction reaches certain critical concentrations of its ingredients, other burning processes may take place. In fact a whole sequence of burning processes, depending on the initial size of the star and the initial concentrations, can take place, in which all of the heavier elements are made. These occur at a series of rising temperatures. It was such a fast series of large stars that 'quickly' (a million years or so) burned up and produced all of the elements heavier than helium in the universe.

This happens because a number of types of stars run their course to where the gravitational force can no longer hold them and they explode as nova or supernova and 'pepper' the slower smaller stars, stars with this new material of heavy elements. But those issues are part of the story of the start-up of the cosmos, and that story we said we will discuss later.

Any new principles? Apparently not. We found more evidence for hierarchy. Atoms can cooperate to form a gas. If the atoms heat up and bang on each other very vigorously, they break and form nuclear particles. These now cooperate to form a gas, in fact a stellar gas. The 'enclosure' is gravity, no other 'wall' is needed.

But that is where we snuck in another principle. Note that the large scale gravitational force became the authority from above. It impressed its authority on the nuclear particles below, and organized them into a field system, the star, which now becomes an atomism. The principle is subtle: New atomistic systems arise when two force systems interact on matter-energy to produce an atomism. That process is a general quantization. (Quantization - the formation of discrete entities, often referred to as 'quanta'.)

The two force systems? Gravity interacting with the centrifugal force associated with a large rotating system of matter created the quantized matter-energy field. The fact that in that field, a second process could take place, the interaction of gravity and the strong nuclear force to produce a quantized burning star is a second aspect of that quantization. The first aspect was responsible for the appearance of spiral arms in the galaxy, and lumpiness in the spiral arms. The second aspect was responsible for the stars.

Complex, right? Yes. You can see that there is really a lot of social history and evolution taking place out there, if you will only go to the trouble of learning the stars' language and listening to them. Of course the troublesome problem is that they are too old - billions of years old, and what youth wants to be concerned with such hoary old age?
Chapter Five - How You Run Yourself - and Your Family

You are a human atomism within your social biological human species. You are a complex self-actuated autonomous atomism. What does that mean? It means that you have lots of internal factory, that you run yourself and that you run your repertoire of actions independent of time, again and again. Inside you, you have a sensory and motor system, a command-control system and a metabolic system. You have senses that give you 'information' about the relative location and state of motion of all things in your local environment; you have means, your command-control system, for interpreting that sensory information and responding to it by motor action. You are equipped with various internal engines to affect that motor action. You have a metabolic system for ingesting free energy and materials, and converting that energy to the required motor action and support of all internal systems. Quite literally you are a factory. A catch-phrase for your overall actions is that you perceive to eat to move so that you can perceive to eat to move; you process that food, and intermittently you can reproduce.

But all other living systems have that kind of behavior. What is the difference between you and them? Basically, there is only a variation in degree. The more primitive living systems, have a rather 'stimulus-bound' repertoire of action modes (they too are complex systems), that is their response is a rather highly bound stimulus-response set of actions. As one ascends in the internal command-control complexity of living species, one finds a greater number of branching paths of action selected by the internal factory command-control apparatus. The response is thus less stimulus-bound; instead it is recognized as a freer stimulus-organism-response chain. That freedom to make branching internal decisions (e.g., to be or not to be, to move or not to move) is associated with the increased complexity and number of levels associated with an internal nervous system.

An elegant description of the process and machinery of increasing complexity of such machinery in living systems may be found in Elliott's The Shape of Intelligence. Very readable descriptions, in a semi-technical sense, of complex behavior can be found in Iberall, McCulloch's article "The Organizing Principle of Complex Living Systems" (Journal of Basic Engineering, ASME, June 1969), and at the primitive single cell level (in which the essential process of command-control of behavior is identified at that cellular level) in Llinas, Iberall's article "A Global Model of Neuronal Command-Control" (BioSystems, May 1977). A brief clue on the evolution of the command-control capability is the following: in primitive organisms, the primitive nerve cell evolves its capability to transport or export chemical materials as signals and thus use them for communicating an excitation. In subsequent forms, that chemical export-transport is augmented by a speeded up electrical transport that permits coordination via elongated nerve cells. However, the basic chemical export-transport is never really lost.

That freeing up of the internal response, and the apparent plasticity of the internal nervous system, leading to what are called cognitive capabilities, often identified with "free will," is most highly developed in the human species. We do not have to discuss, here, in any detail, the increasing capability as it is found in mammals, more specialized in primates, and even more specialized in Man's hominid ancestors. The greatest gain seems to be associated with sufficient brain capability to use tools (as material abstract extensions of an animal's motor systems), and later language (as communicational abstract extensions of an animal's ability to represent all sensory and motor information and translate, by some analog, similarity among any or all sensory or motor modalities. Why is a smell like, a taste like, a feel like the sound of music, like a memory? Such translations, by verbal analogies, is quite a remarkable and complex process. Once again, we will express it simpler, broken down. The human animal senses. It
takes different perceptions and represents them by an abstraction. That abstraction is used inside and then outside as a language. In humans the abstraction covers a very broad range of perceptions.

So we may start from the elementary question. What conservations, and what potentials does a living system, in fact your living system, have to deal with essentially?

As we saw with bacteria, the simpler living systems have to deal at most with four conservations. They must take in and deal with matter, with energy, they deal with these by characteristic action modes. That is all that concerns the individual atomism. If we turn to the species ensemble, growth and reproduction have to take place.

Those minimum conservations are the same ones that confront you. You have to take in turnover and replacement materials (your internal factory can make many of your required chemical molecules from some basic constituents, but not all); you have to take in free energy; and you achieve your life performance by your characteristic ring of action modes. As an individual, you need not reproduce; in the higher species the more complex task of sexual reproduction is not compelling on every adult. There is little doubt that part of the internal genetic code, in creating an apparatus for reproduction within you, also provides the modes for putting 'pressure' on you to perform in a sexual mode. But one is faced largely only by the following 'hard' requirements in modal performance. As an adult you have to take in perhaps 2000-3000 kcal/day in free energy (depending on size), your chemical potentials in materials have to be drawn from fats, carbohydrates, protein, minerals, and vitamins. The requirement is for about 70 grams per day of protein minimum, and other fairly specific requirements of other materials. You may have many branching tastes on how to fulfill those requirements, but that is more a matter of availability, and part of your self-actuation and autonomy. (Compare your present diet with that when you were a child.) Animals have to have some branching capabilities to 'select' their material-energy diet if they are to survive. It is built into the genetically cast machinery. A gorilla, as a vegetarian species, composes a diet as a rather elaborate wandering banquet. What that means is that the ring of action modes is rather loose in execution in higher animals. It is not 'hard wired' or rigidly sequenced. Yet it works quite reliably.

Consider one common preoccupying mode, sex. The human individual, when it comes to a sexing modality, a mode that occupies perhaps 1-2% of his or her action space, has many options. There may be 'abstinence.' With abstinence from any sexual intercourse, there may be wet dreams. Others may masturbate. Some may engage in intercourse with casual partners. Nevertheless, as in all other species, there are generally quite elaborate schemes by which reproduction comes off rather reliably for the species. The socialized family is the most typical scheme. Where human mating patterns fit among other primate social patterns has been described by Eisenberg and his colleagues. We do not have to go into details on all the social forms of various animals, including people. We just note the proviso, that while sex is an essential mode for the species, completion to reproduction is not an essential act for the individual animal, a fact for most species above some primitive levels.

To give the flavor of action modes in higher animals, say mammals, ethologists (for example, Scott) identify about nine characteristic modes. These are

- ingestive modes
- eliminative modes
- investigatory modes
- care-giving modes
- care-soliciting modes
- sexual modes
- conflict modes
- imitative modes
- shelter-seeking modes
More primitive and general, we can identify
- aggress modes (regardless of whose space is being aggressed upon)
- defense modes (regardless of who is the aggressor)
- maintain modes.

When we come to the human, perhaps identified somewhat differently, we can count about 20 different action modes:
- euphoric mode
- drink mode
- void mode
- anger mode
- escape (little motor or sensory input) mode
- laugh mode
- aggress mode
- fear, fight, flight mode
- greed mode
- envy mode
- sex mode
- anxious mode

The 'purpose' of the ring of modes is to satisfy the fundamental conservations, of chemical material potentials, and energetics.

Now you, human, with your plastic nervous system may elect to run through the ring of modes in many different kinds of sequences (yet note, that people get hungry after exercise, sleepy after a day's activities, etc., for many characteristic coupled chains or fragments of behavior), or you may tend to spend much of your time in particular modes. You may be 'intellectual,' or 'athlete,' or 'observer,' or 'compulsive eater.' Write down a usual life pattern in an industrial society - 8 hours work, 8 hours sleep, 8 hours personal attention; or the developing American pattern, 7 hours work, 7 hours sleep, 4 hours personal attention, 6 hours television! Such apportioning of activities have become the typical 'factory day' of the human. Your great cognitive capabilities are more fancied by poets and philosophers than by real people! But those choices are your own. 'Free' (?).

Isn't there more to life? You are 'free' to choose your modes or concentration of effort as long as you get the fundamental matter and energy and primitive modes in (deprive yourself of sensory involvement, and be surprised on how this can lead to hallucination, anxiety, or even terror - try to prevent depression or anxiety when things go wrong). The point is that as species move toward less stimulus-binding, and the rudimentary modes are more easily achieved in a particular environment, there is greater freedom in branching paths (they all involve comparable energetics, so there is no great charge for one branch over another). Those branchings, matters of mathematical-physical stability, have little selection pressure. Thus they are governed less by physical law (although they generally have to come off in the species with adequate frequency). If that is the case, something other than law governs. That which governs is a strategy for performance.

If not tightly bound or selected by environment 'pressures,' human beings elect a strategy, largely a cultural election, to fill out their action space. That is a social pressure that arises from the ensemble to equilibrate the environmental pressure. How behavioral modes are selected, becomes freed. Perhaps you may feel free to elect whatever modal schedule you desire, but you may find that biological or social pressures may mediate your selection. Try it. Review your
daily modes of behavior. Try to see how much 'freedom' you have in selection. What do you do after dinner if you have no friends and no compelling activities?

Oh yes, we have neglected one additional conservation, one peculiar to modern man, in existence only in the past 10,000 years of fixed settlement, dependent on agriculture, within constellations of urban settlements. (See Hamblin's The First Cities, for a clear depiction of the first trading constellations of urban centers and their reason for being.) This new conservation is that of value-in-trade, or value-in-exchange, the economic variable now identified with money or credit. In every transaction, value-in-exchange is conserved. It is a new variable invented out of the human mind.

If we asked any other species to deal with their interpersonal actions by value-in-trade, there would be great difficulty in comprehending the idea. Neither would it be understood by Man's early hunter-gatherer ancestors, people who existed for 30,000 years of Man's 40,000 year existence. It wouldn't even be understood in agricultural villages or forest economics.

But once a group of cities come into existence in which they began to trade materials, say because of some shortages or unbalances, then the notion of value-in-trade was invented as an abstraction, and it began to be treated as a conservation. At the moment of 'trade,' an equality of 'value-in-trade' is perceived by both traders. It doesn't matter whether coercions exist (e.g., "Your money, or your life," says the robber; "It's a bargain," you say, handing over your money), or that the value changes after the exchange. That now is a new conservation, as far as you are concerned. So, as you well know, in dealing with your life, you must deal with and balance money or value-in-trade as well as materials, energy, and action modes. Note how much that new conservation limits your freedom of action.

It is timely to turn to the potentials which you have to operate with. Again, you have to operate in an environment in which you can draw upon the temperature potential, the free energy potential, the material chemical potential, (these you may prefer to call, loosely, the climatic, ecological, geographic-geologic potentials), a stored value-in-trade potential (the economic potential), the genetic potential (oh yes, that still remains aboard chemically in germ cells), a new one - characteristic of Man's hominid ancestor - the technological rate potential, and one that has been characteristic of Man during his active history - an epigenetic value potential. The latter two are new. They are potentials carried inside the organism, peculiar to the hominid (Man's ancestors), or the later Homo branch. The technological rate potential is the capability to develop and use tools (and technology) and add to it generation by generation. Bees use complex structures as 'tools' for living, so do birds. They do not add to that capability generation by generation. Their technology is largely locked within their genetic potential. Loosely speaking, what that human capability does is to increase the power handling capability of the organism, or modify its action modes.

The epigenetic value potential is the capability to memorize and transmit an entire learned heritage of methods and techniques and contained strategies for conducting life by modified response processes. The strategies are contained among your value system. A species could have an epigenetic heritage, all of methods without technology. And the hominid species had tool technology without a modern Man's cultural heritage. In fact we suggest that hominids didn't even have our language capability (the ability to form abstractions rapidly at about 10 symbols per second). Thus the two new potentials are independent, and both are major potentials arising now out of human mind. In time, the technological rate potential may become archaic, and show no more change, but that is still far off.
So you exploit your life style, dependent on the available potentials. You may have been just as bright 20,000 years ago as today, but the technological rate potential limited what you could do then, as it does today. That is how you live.

Given the existence of this physical construct for life, are you good or bad, or moral? We don't know. Read history. We find all mixed up in that story. From the history of a period and from the characteristics of your body and brain, and from any set of existing boundary conditions (e.g., name, a time and place and some details of the prior history), we can surmise your general behavior as the distribution function for your group. At least that is what we are claiming with our homeokinetic science. So we think we know how you have run yourself and will run yourself in history.

How about your family? We don't have to go at it in so much preliminary detail as we have spent on you. The rudimentary idea has been presented.

Generally boy meets girl (in adolescence), boy loses girl (not necessarily too often), boy gets girl (most often). There are many variations to the pattern. Murdock's Ethnographic Atlas has catalogued all well studied 'independent' cultures. These familial patterns are laid out. Boy may get many girls; girls may inherit more than one boy; boy or girl may get an extended family; there have existed boy-boy, girl-girl associations, etc. These issues are studied in anthropology in great detail.

But again, basically, the problem is simply a new level of chemical bonding, this time social chemistry, involving the forming of human molecularities, with reasonably well defined rules for the making, breaking, and exchanging of bonds. If atomic bonding is studied by ordinary molecular chemists, and nuclear bonding by nuclear chemists (mostly specialized physicists), then human bonding is largely studied by anthropologists or social psychologists, as a functional process. They may not recognize the true 'molecular chemistry' of the bonding, but that task still lies at the frontiers of neuroendocrinology, neurophysiology, neuropharmacology, and neuropsychiatry. There are already many pioneers at that interface, and in fact, we have been working to do our bit. Literally the bonding between people depends on the chemical and electrochemical flow streams within the nervous system and the neuroendocrine systems. They create exchange forces related to the exchange forces we described between atoms. Social scientists will not like this language. Nevertheless it is on the scientific agenda of exploration, and it is one of the reasons we have written this book of exploration. We are trying to raise your scientific consciousness. In referring to such processes, we are talking about methods more selective than popping dumb pills to grossly or nonselectively change moods or engagement to life.

So you choose a mate for whatever 'reason' - sex, bodily attractiveness, behavioral attractiveness, parental wishes, money, drunkenness, envy, escape. You have children. You don't divorce or separate (if you do, you are not a family any longer, and we are not writing a divorce manual). What is new or different in the family constellation?

The basic conservations remain unchanged. The only difference is an enrichment in action modes. Out of the individual action modes, there arises a ring of cooperative or social modes in the family, and in particular, in humans, a division of labor. Whereas other animals generally form social relations on pecking order chains, humans form triangular relations, e.g., the relation of A to B and C, and those form more complex lattice-like arrays. These are highly influential in families, starting from the male-female mate pair (with a characteristic division of labor in work patterns) and extending then to the father-mother-child array (or disarray if that is how you view it). Here then is the end of the rudiments of physics, where the applied scientific
aspect of "how to manage" begins. We send you to the more detailed literature, if you are interested. Again, a harmonious pattern of modal interrelationships is to be desired. It requires great accommodation and personal atomistic skills to achieve. It must not only be of harmony inside, but outside in its ecological niche. Note that we are showing you that to understand how systems work is relatively easy. This does not mean that running a system is easy.

We told a human story. But except for its additional specialization, the story would have fitted just as well for the conduct of any other living species in its niche, e.g., how to be a bull or cow, and how to raise a family. What you basically have to start from is the characteristics of its command-control nervous system, and how it governs modes, regardless of how you discover that modal system. Every manager of domesticated species knows that. (Have you seen people, instead of or after raising a family, take on the familial rearing of a pet?)
Chapter Six - Weather, Climate, and Its Many Scales

We have told you how a gas works, how a star works, how a bacterial colony works, how you work. Now we begin our tour of some of the more complex systems, as far as unraveling their very extensive stories. We did not lay before you a very basic principle, that was implicit as soon as we indicated that systems (particularly noticeable in complex systems) have a birth assembly, or start-up phase, a life phase, and a degradation or dying phase. The long life phase of a system, with its autonomy 'independent' of time for that life phase, is made up of a spectrum of different process scales by which its required action modes come off at very many scales. What is a spectrum? The simplest case is an extensive range of different colors of light as seen in a rainbow. But what that really means, each color being associated with a frequency of oscillation of an electromagnetic wave, is that a spectrum refers to an extensive range of phenomena taking place with different frequency scales, or - as a reciprocal description - at different time scales. Your heart may beat once a second, you breathe once in four seconds, you eat three times per day (a frequency), you sleep each day, adult women menstruate once a month, some animals molt once a year, you reproduce a few times in a 70-year lifetime, the species may live for a million years. As you can see, there is an extensive spectrum of temporal (time-dependent) processes associated with a living system. For example, for the individual human there is a spectral range from 0.1 second, for the characteristic time of an individual nerve impulse, to the 90 years of the life span. That near hundred year event is approximately 30 billion times longer than the nerve impulse. A great number of process time scales funnel action throughout the human organism.

Of course, one could argue that the nervous impulse is not a fully coordinated behavioral mode throughout the organism. True. It is a modal response of an atomism, a nerve cell, in the multicellular organism. So, if instead, we suggest that organized behavioral complexes in humans (or more generally mammals) begin at six seconds, as fragments of total organism attention, the spectral range is less by a factor of 60, 'only' a range of a half a billion. But it is not such details we wish to argue. What we want to point up is that except for fuzziness as to where to end (death of course is truly death), complex systems exhibit broad spectral ranges in their modal behavior. In fact different configurations of the 'basic' modes of a system are arranged at different time scales. You may urinate now, and drink a few times a day, your extravascular water may be pumped back every night, and there may be seasonal fluctuations in your body weight. Yet these may all be different spectral expressions of regulating the water content of your body.

When we came to the planet, or in particular our planet, even neglecting life (which we call the biochemical system component on a planet - not all planets have such component systems, in fact not all stars have planets) there is a very rich spectrum of modes. We did not bother to sketch out the very rich spectrum of stellar modes. We did hint at them, by telling a little about their life, but we did not tell their life stories richly. Scheherazade, the story teller, could be easily outdone. (The trouble as we indicated, is that if we told too many 'old men or old wives' tales, you would be bored, and miss the morals. So, like Scheherazade, we have to amuse you - for your benefit and ours (believe it or not, our sanity more than our pockets. We write this from moral fervor.))

At this point we will not bore you with the restless earth and the restless oceans. You may not sense it fully, geological time scale is generally so long and slow, but gradually the movement of continents and earthquakes are beginning to penetrate your consciousness. Flooding you have known of for a long time. It is an annual event. Severe floods occur perhaps
every 50 years. But as civilization becomes increasingly binding, the movements of the restless earth become more apparent. Are Californians not aware of the dangers and risks? Can you take refuge in the wrath or wraths of God to offer you explanation or solace?

But instead of moral exhortation, perhaps it is better if we tell you some of the story of weather and climate. What is to be learned from that story? A physical form of 'life' on earth, climate and weather, is as rich as biochemical life. A subsequent moral, that biochemical life is likely due to geochemical processes, we will save for later. But it is a useful underlying reflection to dwell on, as weather and climate unfold before you.

Weather and climate cover a spectrum that extends from each passing local gust of wind, or cloud, certainly from daily patterns associated with a rotating earth, to near weekly, seasonally, yearly patterns, on to mini-climates in the range of centuries, to hundred thousand year fluctuations of 'recent' Pleistocene (few million years) Era, on to changes in the hundred million year ages (not too relevant? - if you want to know where your next oil or coal is coming from, this is the time scale of processes you must understand), and to the very evolution of the atmosphere and planetary climate for the billions of years of life of this planet (five billion). That range, five billion years to one day is a range of 1500 billion to one. It is very much like the entire range of the system of living biochemistry. And, in fact, the story of living biochemistry is very much tied up with the story of the atmosphere and climate. So let us see if we can sort out some of the major processes that make the atmospheric machine work.

First, drop the seasons (that is, straighten up the tilt of the earth's axis, let the earth go around the sun in a perfect circle, drop the moon). Leave the earth covered three quarters by water. Don't pay too much attention to the 'slow' daily rotation of the earth, except that it exists to equalize things on all sides of the earth.

We can suspect, from our earlier discussions, that the conservations and potentials will be the usual - chemical potentials or various mass species on earth (they are bound to earth by gravity), and free energy potentials from earth and solar sources, temperature potential, conservations of mass species, energies, momenta and action modes (there will be a complex mishmash of both simple and complex atomisms). Any significant population conservations? No.

Put your hand near a hot lamp. What happens? Your hand heats up. The same thing happens to the earth. The sun radiates (loses) energy, which is received by the earth, by ground, atmosphere, and waters, and which warms them up. How hot? It depends on how hot the lamp is and how close you put your hand. Also the state of your 'hand' depends on its materials. Substitute a flask of ether and it will boil away. Substitute volcanic lava and it will be hot solid. Put a flask of water and it may remain liquid, it may freeze as ice, or it may boil as steam. The same two things happen to the planet earth. The interior of the sun has a temperature of about 20 million °C, but its surface radiates at about 5000°C (like a very hot incandescent filament). At the earth's location, the earth balances at an average surface temperature of about 10°C (50°F), because of the radiation it receives. We should have pointed out that the earth's temperature is arrived at as a balance between what it receives and what it radiates. If you put your hand in the hot incandescent source, your hand may take on that temperature. When you receive heat from such a source, by radiation, you also radiate heat to whatever your hand is pointing out to. The earth (or your hand) points out to cold space. The sun warms the earth by appearing only as a very 'small' hot region in the sky. (Don't try to boil eggs from the heat of a distant star, although presidents like to receive such light, amplify it greatly, and turn on switches that start up World Fairs.) So a 10°C balance from a 5000°C source sounds right.
But in that case, you can see what will happen. Depending on materials available, some will form a congealed or frozen solid, some will form a gas. As we indicated, physical processes can lead to condensed matter. Cool a gas (that is remove kinetic energy of motion from its atomisms) and the atomisms will condense to liquid; if cooler to solid. Water freezes to solid below 0°C. (This was how 0°C was defined.) Oxygen, nitrogen are gases at such temperatures. It was interesting, at the turn of the century, when each of the resisting gases were finally liquefied or solidified by extreme cooling. These two gases liquefy at perhaps –150 °C. (Absolute zero of temperature is said to be found at -273°C. An absolute temperature scale, the Kelvin scale, counts up from 0°K = -273°C. Thus 0°C = 273°K. For the sake of reference, the apparent temperature of space, not the sun, is about 3°K. Helium, the most recalcitrant of elements solidifies at about 2°K). The chemical compounds that make up rocks may melt at about 2000- 3000°C. Thus at 10°C, one finds the segregation of materials on earth that we are accustomed to, a rock (lithospheric) solid earth, a condensed water, a gaseous atmosphere. Our current system story will relate to that atmosphere.

Our atmosphere is made up of nitrogen, oxygen, argon, carbon dioxide, and a variable amount of water vapor (gaseous water, which can be called cold steam. Breathe on a mirror and you can watch it condense.). Not all planets exhibit the same materials and the same phases. Comparative study of planets, particularly since rocket explorations, has only very recently become a detailed study, so the existence of gas, liquid, solid phases requires specific detailed study in each case.

Beyond the question of the nominal temperature of a planet, because of its governing stellar source, and its distance from the central star, there is another property that relates to its surface phases. The surface absorption characteristics of a planet, e.g., its gaseous, liquid, or solid cover, can determine its radiation losses. When that absorption cover has certain mirror-like properties, we refer to the existence of a 'greenhouse' effect. The radiation received from a hot source has a spectrum (a frequency distribution) characteristic of that hot source, e.g. 5000°C, that we recognize as a very bright white light. (No accident. Our eyes have evolved to provide us with that characterization of ‘visible’ light as white.) When that radiation is absorbed as heat, it is re-radiated from a much lower temperature source, e.g., 10°C. That radiation is very dull. Look at the barely red temperature of a cooling electric burner. That is a radiation temperature of perhaps 400°C. Your hand (like the earth) has a cold infrared (beyond the red, which is no longer visible) temperature. Women today are taking infrared thermography 'pictures' for breast cancer detection. Space is always receiving such infrared thermographic pictures from the earth.

Anyway, that is the greenhouse effect, a re-radiation of electromagnetic energy with different spectral frequencies, than which was received. It is the cause of heating in greenhouses. The half mirror-like absorber in that case is the glass. In the atmosphere, we have two half mirror-like absorbers - the water vapor constituent, and an ozone constituent which is found in the upper atmosphere. The water vapor constituent stems from the fact that the temperature range on earth, approximately -70°C to +70°C, both freezes and steams water. The vapor pressure above water or water ice has a very considerable range, from near zero (one measure is the humidity - at freezing weather, a low humidity of say 10 to 30% represents a very low partial pressure of water vapor or gas) to an appreciable fraction of the total pressure of the atmosphere (i.e., a partial pressure of water vapor up to 100 mm of mercury pressure out of 760 mm of mercury total pressure. Various chemical components in a gas contribute additionally to the total pressure. Loosely speaking that is a measure of their chemical potential).
The ozone component is created by a photochemical reaction in which the oxygen molecule (two atoms of oxygen) are affected by the absorbed radiation, undergoes a chemical reaction and forms a much less stable ozone molecule (three atoms of oxygen).

Other planets do not necessarily have these same constituents. In fact recent physical theory has begun to account for the differences in atmospheres, even when the initial ingredients are not too far different. (This is not to say that all planets have the same ingredients. There are some important differences as one gets further away from the central binding star, the 'parent'.) There is a current interesting speculation that has recently been announced. (By Michael Hart about the evolution of an atmosphere. While it is one of the first such speculations, the theory sounds 'so right' that one knows it is on the right track. One of the marvels of physical theory, and its parsimony, is that it is a physical theory so easily modified in some of its intrinsic assumptions, and the consequences to probe at its self-consistency with experiment comes rather easy - to the trained. The possibility of testing consequences of one set of assumptions or another is generally then also easy. We are not asserting that this new theory, by Hart, is absolutely right, but is quite transparent, and it is easy to modify the theory if its consequences are caught up in poor consistency.) His calculations suggest that the existence of a gaseous atmosphere is a marginal thing. If a planet is a little too far, for a given size, its atmosphere can be lost to space. If the planet is a little too near, the atmosphere can have a 'runaway greenhouse effect' (we'll explain). In the model, the three planets, Venus, Earth, Mars, furnish a first probe of the hypothesis. Venus has a runaway greenhouse effect, Earth has an atmosphere, Mars has lost its atmosphere. We may refer to this as the story of the three bears, with their 'just right' condition.

So let us concentrate first on the Earth to see the basic story. The Earth's atmosphere is heated by the sun. There is a radiation flow in, and a radiation flow out. The earth rotates slowly. What might one expect? (We don't want to attend too much to the rotation, just enough to equalize or average the heating on all sides of the earth.) What happens is that a global convection pattern arises around the earth. The gas is heated at the equator. By the equation of state, the gas is less dense. It thus has less gravitational pull. It thus rises at the equator. It is colder and more dense at the poles (the density of solar energy is spread over a much larger unit area because of its obliquity). Thus the cold air descends. Draw such a picture. You immediately can see the result. There are two rolls of convective flows taking place around the earth. They both rise at the equator; one arches over the earth to the north, the other to the south. They each flow poleward, high in the atmosphere. They descend at the poles, and then flow toward the equator along the earth, both from the north and the south.

Wouldn't that be a fairly lovely pattern of winds around the earth?

Have you ever seen such a convective pattern? Certainly you have. Every time you put a pot of water on a stove and heat it, such a convective pattern develops within the pot. Of course the pot is not a sphere, so that the convective pattern doesn't have that precise two-roll form. Instead it breaks up into a variety of smaller rolls, particularly accentuated by the hot metallic walls. And so we have developed our first wind pattern, convection from the poles.

But now we want to jump to a more subtle facet of the movement, the humidity in the atmosphere. The 10°C average surface temperature actually can be estimated to arise more from a surface temperature of about 20°C at the equator and -35°C at the poles (if it weren't for water-ice covers; because of ocean covers in polar regions, the polar region is more nearly 0°C over polar oceans, and -35°C over polar lands).
In any case, harking back to our kettle, what is the humidity that we expect over an equilibrium or near equilibrium liquid surface? It is, by definition, 100% humidity. The liquid 'boils' off enough vapor to saturate the gas phase with an equilibrium partial pressure (we'll come back to such physical processes later). That saturation is said to be 100% humidity. Liquid will condense (as well as evaporate) off any surface in that gas space. Any lesser pressure will represent a non-equilibrium process by which saturation has not been achieved.

Put your hand over the boiling pot. Notice that your hand immediately gets all wet, dew soaked. (For definiteness, put a lid on the pot, and watch how it gets all dew soaked.) Clearly we must be somewhere in the vicinity of saturation, because every evening, when the sun goes down, notice that everything left outdoors gets dew soaked. The dew point is defined by the cooled off temperature of a surface at which water (or vapor) condenses.

But if we ask the question, what is the average humidity in the atmosphere, the answer is about 60%.

What does that mean? It means that the atmosphere, contrary to the space above the heated water in the pot, is not in a thermostatic equilibrium. There must be flow fields, there must be gradients maintained. Our problem is to indicate this first rather subtle one.

Return to the pot. We have not told a complete truth. If you watch the water on the lid, you will see that not only does it condense but at times it drips off back into the pot. If you want to increase that drip cool the lid. (It is cooled by the air, if you are heating the pot.) That water runs back or ‘re-evaporates’ only if there is a flow cycle. The vapor pressure in the pot has to be less than saturated. Then there is a gradient that will permit the water in the pot to evaporate. It condenses on the lid. Water runs or shakes down. More evaporates. Thus a flow or thermodynamic equilibrium can be reached. Heat comes in either from the bottom or from the cooling on top to maintain the process.

What caused that drip from the pot lid in the case of the earth? It was the rainfall! On the average, a rainfall of 20 inches per year both rains down and evaporates over the earth. Thus we have shown that the atmosphere is intrinsically tied to the hydrological cycle.

Rainfall on earth evaporates or runs off in rivers.

And what creates that hydrological cycle? A nonequilibrium thermostatic processes related to the continuing flow of atmospheric gas around the earth.

In the pot, it was simple to see what made the rainfall. The lid is cooler than the bottom of the pot. But the more important analogue requires some further shaking. What makes the rainfall? We cannot supply a long detailed complex answer now. Suffice it if we add a few more ingredients.

There is no 'hard' lid on the earth's pot, but there is a soft lid. It is the cloud cover of water vapor. A cloud is a very sophisticated physical structure, perhaps as sophisticated as you. It adjusts and adapts in most remarkable ways. Like most complex systems, it is metastable. It can very easily go more than one way. It can rain; it can soak up water; it can rise; and it can descend; it can blow away.

Two of the important characteristics of the atmosphere is first the 'law of atmospheres,' the pressure varies in the atmosphere in accordance with how much weight of air there is above any level. The winds hardly have any effect on that law. As one goes up in the atmosphere, the gas temperature changes. So note that as you go from ground temperatures above 0°C, temperature will be found to fall with altitude and will reach a temperature of 0°C, a temperature at which appreciable water vapor will likely freeze. Thus there is the chance of a uniform cloud cover, a sort of saturated air sponge at some particular level. The actual change in temperature
with altitude (the lapse rate) is about 3°F per 1000 feet. That results in the common low cover clouds at about 6000 to 8000 feet. Other subtleties of high cloud covers we do not have to deal with. We only want to establish a feel for the beginning of the story.

So what does one find as the variation of temperature with altitude for a stable atmosphere, stable in the sense that it is a fluid flow atmosphere rather than an equilibrium atmosphere (the gas in the pot of water).

Loosely speaking it is an 'isothermal' atmosphere, a constant temperature as one climbs in altitude. But every meteorologist in the world would blow steam out of every orifice with their statement, so we have to explain. Loosely speaking, it is 'isothermal,' but the actual temperature twines around that isothermal level. Thus, in actuality, the temperature falls from its average of 10°C nearly to about -55°C at 35,000 feet (a common altitude jets fly at - think about the temperature the next time you are out there). That is the tropopause temperature, a constant temperature for the next portion of the atmosphere; whereupon it then rises to complete the first entwinement back to near ground temperature; there is another pause, a second fall, a pause, and basically a final rise. The second lobe and its final rise are for practical purposes almost devoid of any molecular density. One halves the pressure (and thus the density) approximately every 20,000 feet, so that five miles up there is only a few percent of the atmosphere left, and by twenty miles up almost no atmosphere.

The important question is what does that twining temperature pattern mean? Basically it means, in the Hart model, that if you tilt that 'average' isothermal line about which the temperature lobes entwine, you get a lost atmosphere as on Mars, or a runaway atmosphere as on Venus.

In a runaway atmosphere, the temperature gradient - ground to top - is so great, that the atmosphere almost literally boils at the bottom. For that you have to have an atmospheric component that can serve as the carrier. On Venus that carrier is carbon dioxide. Our atmosphere started out as a carbon dioxide atmosphere, and evolved its chemistry, due to its physics, to the current nitrogen and oxygen atmosphere. (That statement is no casual statement. That process is what made earth's geochemistry obligatory, and thereby, earth's biochemistry obligatory. Note that sun and planet and constituents and position make hydrosphere, atmosphere, lithosphere, geochemistry and biochemistry perfectly possible and obligatory paths. There is no indeterminate freedom, given a range of certain constraints. More on that later.) On Venus, the surface temperature is 900°C, not 10°C; the pressure is 100 atmospheres, not 1 atmosphere. A 'small' change in greenhouse effect is phenomenal.

So now we must add some more details for the wind structure around the earth.

We have neglected the rotation of the earth. Because of the transport process of shear viscosity, the atmosphere is dragged along by the earth (whereas higher levels tend to stand still). That would lead to zero wind at the surface and a prevailing westward wind up high (in addition to the thermal convection). But then the location of continents above the ocean surface have an additional influence and would tend to quantize the prevailing wind structure.

However, there are equally compelling hydrodynamic forces. The flow fields around the earth are not stable as just two rolls, even with a rotational twist, and some periodicity in winds developed by the continents. Vertically rising flow fields, due to density gradients, are unstable, and so they break up into cells. The relationship to the boiling patterns in a pot of water is much closer than we had suggested at first.

So basically, you get a lattice of cell movements (in a flat pan of water, heated from below, the instability is known as the Richardson instability, and the cell movements as Bénard
cells. Once more we see that dynamic flow instability creates flow forms. Looked at from space these cells look like a nesting of near circular patterns alternating in swirling clockwise and counterclockwise. These cells move in characteristic flow patterns and make up the average wind pattern in the atmosphere, the characteristic fluctuations in weather patterns of the near weekly time scale (they make up the large scale air mass movements). They support the two lobed temperature distribution, and the average humidity in the atmosphere. A lot hangs on the form of that flow instability.

The details of how the actual prevailing wind distribution develops around the earth is not easily told. It was not obvious or apparent to the great meteorologists of the late 19th and 20th Century, and is only becoming clarified in the past decade. We would prefer to let them tell you the story in a next generation of textbooks.

However, you may now sense some of the time scales in a 'stable' atmosphere.

The earth rotates, thus the day-night fluctuation.

The large air mass movements, thus the near weekly variations in weather. (Look at the reports of the variation of daily minimum and maximum temperature which are issued monthly and published in some of the more inclusive newspapers.)

The earth revolves with an inclined axis, thus the yearly-seasonal-variation.

The earth is affected by many forms of electrical phenomena in its travels around the sun; these are likely influential in determining rainfall. Other similar influences may cover events in the range of hours to a century.

The earth has many wobbles in its revolutions; these create temperature effects in the range of years to a hundred thousand years. Many efforts have been made, with as yet incomplete success, to involve small changes in the sun, such as variations in the solar radiation (the solar constant), or electrical and magnetic events associated with sun spots.

Hundred million year passages of the solar system through electrical field, and dust processes in galactic spiral arms have been conjectured as influential in the long term climactic ages of the earth, e.g., perhaps 5-10 ages since the Cambrian Age.

Long epochs relate to the evolution of the earth itself, its lithosphere, continents, hydrosphere, atmosphere, the chemistry of its atmosphere.

You may not feel comfortable with the 'explanations' (or lack of explanations) of an atmospheric story here, but at least you must feel some sense of its complexity. While the problem is largely only physics (and the chemistry associated with that physics), it is clear that answers lie all in the details of that physics. Only a handful of conservations and potentials are involved, but the story very quickly spreads over the entire life, and history of the earth. If you want real answers, you have to read elsewhere. And there is no one good 'popular' exposition. Perhaps this poorly told story will inspire some of our friends to tell it well. Paraphrasing the Cancer Society's "life is breath," we might say life is all atmosphere!
Ethology is the science of the comparative study of animal behavior. It is a subject which is very strongly based on biology, on zoology in particular. Its basic foundations thus have to relate to the character of the organ systems within the complex organism, and in particular to the coordinating characteristics of the command-control system, the brain of the animal. From these characteristics the social behavior of the animal arises. The richness of the genetic code presents the fantastic diversity of biological forms and their many branding behaviors. Yet they are all targeted on survival, and they run to satisfy a very small number of conservations, regardless of the variety of patternings of behavior to be found. So we must view that maze.

We have looked at a colony of bacteria. We have seen how their internal apparatus determines their action modes, and how the environment then furnishes a 'pressure' for action which selects their reaction social pressure, what they do in unison. Now we want to take that description up to human society.

If you are interested, you may first pass through the behavioral patterns of very simple biological forms (see, for example, Fraenkel and Gunn *The Orientation of Animals*, about motor action in animals, which is fairly interesting). You may want to look at the very complex behavior of the highly stimulus bound insect societies (see, for example, Wilson's *Insect Societies*). You may want to consider his call and claim for a unified science of sociobiology, a subject in very bitter controversy at present. We would tend to take sides in such a debate too. We would suggest that the comparative science of ethology needs a great deal of development before it has competence to more fully comment on the relationships of behavior to internal mechanisms. And the integrative biophysics of such relationships requires even more development before it has any detailed utility for such problems. Our generalized physics is not too severely bounded, because it goes very gingerly at only the very general applications of the laws of physics. We have no objections to move it in toward any particular problem, as for example, toward any specific biophysical problem. But on the other hand, that a sociobiology, based on some knowledge of behavior in highly stimulus bound animals, can trace a path easily to the highly branching social behavior of higher animals is wishful thinking - unless it is prepared to take over and be ethology, physiology, biophysics, and physics itself). You can then move up to examine mammalian behavior. A book that can be recommended for an introduction is Havez' *The Behavior of Domestic Animals*. An alternate is to be born and grow up on the farm (in any country). Note that it has been a stock in trade of Man, all through his existence (as it is of all other living species) to know rather well the behavioral patterns of other living species. It is an important stock in trade for managers. It is an important knowledge for survival. If we consider the modal time scale, in human society, the yearly dependence of the natural ecological cycle on the revolution of the earth around the sun does not have to be emphasized. It is there in the daily market, in our very perception of the nature of time and its processes. These issues are written in common, basically, in all species, and more specifically in the genetic code.

But now we need a more compelling need for social bonding. Is there a general principle for all chemical bonds, regardless of the level - nuclear, atomic, molecular, cellular, organismic? Given environmental potentials atomisms bond via their available force stems to the lowest energetic level at which they can support their survival functions. That principle becomes encoded within the genetic code. When there is greater luxury in the available potentials, when one form has climbed on the back of other forms, new branching capabilities emerge. Thus we have found two types of such branching - externally in the form of functional processes (as in flow fields); internally in the form of encoded factory complexity (as in matter condensation). In...
the living system, we have now reached a matter condensation level where the 'free' bonding of organisms into societies, into social forms that may ultimately be viewed as social 'cultures' (rather than simply biological 'cultures') can take place.

Pass beyond the generalized mammal, domesticated or not. Clearly Man has empathized with these life forms, and many with him, for a long time. That is how symbiotic relations have developed. (Do you have any such doubts for person-to-dog bondings, etc?) The bondings serve mutual needs. Somehow they share a lesser energetics.

Pass quickly up to primate behavior and its bonding forms. There are the very many delightful field studies, reported with increasing frequency in National Geographic. Such field study, primatology, as a specialized form of ethology is certainly blossoming. Does one sense the considerable similarity in human behavior and in the group behavior of these higher ape primates?

Yet they are only remote cousins, on biological branches that may have separated as long as 20 million years ago. They have memory, and communicational systems. They do not have a culture. They do not have an extensive language capability to abstract and transmit information at nervous system rates of perhaps 10-20 bits per second. They do not have an extensive heritage of tools. Tools or methods they use do not evolve or transform generation by generation. They may not be stimulus bound, but their behavior, however rich and delightful it may seem, has a remote if not an archaic quality to it. They do not exhibit an extensive division of labor. Yet we sense a considerable comprehension of their social style of life, how they satisfy their conservations and operate from available potentials. To a very interesting degree, we can live their style of life (as field observers have nearly to do); and they can live among us (as many primates that have been experimented with have shown).

But now we face the question of transition - how do we go from them to us? Or more specifically, how do we do from our common ancestors to them and to us? That has become a very popular subject for everyman to attend to. We can offer you a very entertaining introduction, perhaps not up to the very moment of the history of this rapidly changing subject as the story of transition comes more sharply into focus. The book is Pfeiffer's The Emergence of Man. (A second book, of greater scientific depth, is Young's An Introduction to The Study of Man. Any reader who cannot enjoy those two books should really have difficulty enjoying this book. Love us, love our kind.)

We will not attempt to detail how changes in the genetic code, by actual chemical change in the incorporation of nuclear arrangements, leads to mutations in species. In this regard, the natural field conducts a laboratory with experiments as dumb (or bright) as any company laboratory. By constant experimentation, using the bombarding hammer of high energy background radiation arising from the sun and the galaxy - the genetic code is always undergoing changes at some 'error' rate per generation. It is as definite a process as internal change by natural radioactivity. The biological issue of that process is constantly being tested, generation by generation, for new emergent biological forms whose survivorship has a better margin than existing forms. (There is also a neutral theory of evolution that says that emergent mutation, as long as it doesn't kill, goes along to produce diversity without any significant selection pressure.) Apparently these encoding changes accumulate and 'ultimately' produce an observable change in speciation. Of two competing theories of the process, change takes place by little bits, continuously, generation by generation; change takes place rather precipitous after a long time; the latter is gradually winning the race as the more certain explanation for speciation. After all
the significant time scale for speciation is perhaps a million years, with only moderate steps noted at time scales down to perhaps 50,000 years.

And as far as a specific process among primates, it now appears that the first step taken was emergence of a hominid (man-like) primate who stood erect, developed hand acuity and increased cortical capacity, developed increased visual acuity on the basis of that increased cortical capacity, developed the use of tools (the old or Paleolithic stone age), developed increased socialization and mutual dependence on tools and a division of labor, developed further abstraction (further than the notion of simple tools) in the use of speech, and thus evolved into modern man. The whole time scale? Perhaps 20 million years, with recognizable tool users (ustralopithecines) by perhaps 3-4 million years ago, and the explosion of a number of parallel lines of hominids and homos with increasing brain size for over the past few million years. Then toward the end of a long Paleolithic period, modern man emerges about 40,000 years ago as what is generally described as a superb hunter-gatherer.

The earlier story is still in flux, any detailed fact we would state would be contradicted by one archeologist or another. A 'sound' story for the origins of modern man likely is Klein's Ice-Age Hunters of the Ukraine, or to Clark's The Stone Age Hunters.

The question we raise is how did that modern man, our ancestors, live socially for that extremely long period, 40,000 to 10,000 years ago, the so-called middle Paleolithic period of hominids; and then, subsequently, why - in a physical theoretical sense - was there a change in the thermodynamic (and thermostatic) character of social life? The first long phase of man we regard as a liquid-gas-like phase of evaporation and condensation, a hopping Brownian motion on the surface of the earth like the ones we have described earlier. The second more modern phase, we shall claim later, is a more nearly solid-gel-like phase in which the diffusive motion is very much slower. Man is tied in place, like condensed matter. But, since the species of atomisms (Man) is the same, there must be considerable traceable similarity. It is just like the problem of relating the gas, liquid, and solid phase for the equation of state of a pure chemical substance.

So what is the physics (and history) of Man, the pre-Neolithic hunter-gatherer, and why is it physics?

We have indicated that the physics of complex systems relates to the action spectrum associated within atomisms, and that emerges from the command-control system of the atomism. Well, we are such atomisms, and, as indicated before, we have a fair idea of our action spectrum. So we can a priori indicate the requirements to assemble a viable autonomous group. We can do the experiment in gedanken fashion, a prime example of what theoretical physical reasoning is about, and in fact we can imagine doing the experiment today. The support information from existing primates simply lends confirmatory evidence that we are on the right path.

So think of a currently possible experiment. Under what conditions could we take a group into a wilderness and anticipate indefinite survival? More particularly, discuss such within the context of a much more primitive technological rate potential and support than we have now. We can in part touch on the theme by some knowledge, also, of new colony settlements in the America's in the 16th Century.

A prototype, for such survival, might involve the search for a reasonably ecologically stocked river valley, and preferably in a temperate climate. But we know, as a boundary or start-up condition, that Man's most immediate possible ancestor, Neanderthal man (viewed as Homo sapiens neanderthalensis) had essentially expanded to all temperate and tropical parts of the world, except probably the Americas. There seems to be a cold arctic limit for the success of
that technically less endowed breeding population than ours. (The 'proof' of that thesis is the limitations in successful social life as conducted in the coldest Arctic regions, and as conducted in the hottest most humid tropical jungles. In both, the competitions, of different nature, are quite severe.) Our species seems to have radiated from an Asian or Eurasian focus.

The climate at the time Man emerged was an extensive glaciation on the earth, the bottom cold phase of a hundred thousand year ice age. The first severe modal problem, given that oxygen supply for breathing was no problem, is the discovery of a reliable water supply and reliable food supply. Two million years of tools indicated great familiarity of the new species with hunting tools, clothes making tools, implement making tools. Also a few million years of upright existence in savannas, forests, and tundra indicated great familiarity with all the existing forms of flora and fauna. So now postulate a group survival, given also the availability (in our opinion new) of speech and language abstraction. A word is needed on that subject.

Regardless of uncertainty about earlier ancestry, clearly this new species, Homo sapiens sapiens exhibited all the characteristics of human culture. Beside tools, and the proofs of communal living with assemblages of integrated artifacts, they are the first group who show clear and copious use of abstract symbols and magico-religious symbolisms. They are the first artists, in their cave paintings, in their symbolic, instead of utilitarian, artifacts. (The earliest well known examples date back to 35,000 years ago, not too far removed from start-up dates for the new species.) One is certainly tempted to infer that this was the first species that had spoken language at rapid rates.

So immerse such a group (us) in the ecology of the times 40,000 years ago. Plentiful water and food supply were caught up at the front of the southern-most glacial edge (most of the play was in the northern hemisphere, because - as a globe will show, the likely land areas - Eurasian - were in that hemisphere). The 'front' was a region perhaps 200 miles wide which was well watered by the retreating and advancing seasonal alterations of warm and cold. This is just a specialized form of a river valley, to develop later, driven by the annual seasons. It fits a nomadic existence.

The ecological chain caught up in that front could be seen to be grasses following the melting front, grazers following the grasses, predators following the grazers, man following the annuals, the grazers, and the predators.

Given one of these kinds of configurations - river valley, or fairly seasonably nomadic living following a fairly lush ecology, what sort of social life might one assemble? The division of labor made latent by the human brain leads to reasonable counts on the size and diversity of a group. First one would like to have a strong useful family group – a band of related relatives with few children or elderly walking memories who had good working capability based on hunter-gathering (we have enumerated the modes. Water, clothing material, tools, fires, children, hunting, gathering, all have to be attended to), and there should be a number of such bands or camps, bonded together by its hunter leaders. The survivability of the group should depend on the skill of the hunter leaders to inspire confidence and cooperation among the group. So how large should that group be? Our a priori size suggests approximately 25-50 people. That prediction is made in the usual nature of any a priori statistical mechanical count for a distribution function. What is needed to fill out the momentum or the action space?

It is such estimates that we checked in the Ethnographic Atlas and found to be the case. Small isolate cultures are found in the 10 to 200 size, and it was indicated to us that the groups of the 10 size were more nearly remnant fragments. Stability likely lay in the 25 to 200 size. At
much larger size, such groups would break up into independent groups, separate from the parent
group and conduct its autonomous existence

Second, we made an estimate of the roaming range. This has to daily capability for the
mammalian size. A daily range under 25 miles had to be found (even if a nomadic existence
could range seasonably to change the daily range). This meant likely separations among groups
of this order of magnitude and comparable ranging areas.

This sort of estimate checked both biological data on the variation of roaming range with
animal size, differing for plant eaters, animal eaters, or mixed eaters. It also checked with a
subtlety indicated by the Ethnographic Atlas. Cultures are stated therein to be isolated with 1000
years separation or a few hundred miles. For human groups to exist, there must be contact with
other outbred groups. It should be possible for families or camps to occasionally move from one
group to another, or for males to find female mates in other groups. Thus separation of a few
hundred miles was too great. On the other hand, separations of perhaps 25-50 miles (a few days
travel) seemed right. Experimental data on such groups of pre-Neolithic settlements on large
land areas suggested that average separations in the 50-100 mile range for the entire land mass
seemed to be the magnitude. Again a right order of magnitude.

Thus our a priori picture of nearly isolated groups roaming over their own territory, in
which all of the potentials for satisfying the basic conservations existed, seemed valid, and valid
in the sense that one would be willing to do the experiment in such conditions today. One would
not like to go out with a single family. One would like to bond together a number of families
who seemed to have complementary, even if primitive skills; one wouldn't want too many
children or weakened older people. One would like to have a few strong leaders.

Such an a priori specification is physics, it may also be biology, and anthropology, but
the underlying theory of the specification derives from a physics common to all complex
atomisms. We can use such physics to design nuclei, and molecules, and cells, and people, and
societies, and atmospheres, etc. None of the other disciplines can do that. Oh of course, then
comparative biological and anthropological study can provide us with more details than 'just'
physics, but the central point is made - hopefully.

That society, we can see, is a liquid droplet condensation evaporation model on the
substrate earth. Atomistic man can only live on the surface of earth. It is very nearly ideal gas-
like, like a low temperature water vapor associated with a closed pan with a little water in it. The
evaporative surface would show these trends of slowly moving droplets. One more subtlety.
Given time, these human droplets feel out and map the land. They learn about all the good spots
where societies may live. At the phase we are talking about, many may start out as nomad
followers, but soon they will diffuse over all the land face of the earth, and we can estimate the
speed of that diffusion. It should be about one roaming range (e.g., 25 miles) about each
generation (25 years), a rate of about one mile per year. An individual, even if nomadic (e.g.,
with different winter-summer grazing ranges), becomes familiar with his roaming range.
Movement outward (diffusion) does not take place until a next generation takes its place. That
estimate also checks with human rates of diffusion. Diffusive outbreeding exists in essentially
all living species.

So we see a social process in living systems quite similar (not metaphorical analogy, but
a real physically analogous process) to the one we saw in gases. The living atomism expands by
diffusion to fill out all the space available to it. It is only impeded or stopped by barriers. (The
fields are not homogeneous. One diffuses much more slowly into a cold barren land, than into
forest woodlands. Pre-Neolithic society, even with its difference in modal behavior from other
primates, and with two new potentials - the epigenetic value potential, and the technological rate potential - exhibited motional performance not much different from other primates, or mammals (or plants). That is why, among other things, favorable symbioses could take place in time. Man, for example, adapted very well to the habits of the red reindeer in northern Europe, and lived off its herds.

On the other hand, technological complexity, with tool evolution, kept growing. Would that continue forever? That issue would arise at about the time the ice age ended, with the beginning of a retreat of the glaciers perhaps 16,000 years ago, and the beginning of a warming ramp that withdrew glaciers to their current position perhaps 10,000 years ago as an end to the ice age.

One final comment on this model to point out a not-too-obvious defect. There is no easy way to determine the mortality experience of such 'natural' societies 'in the wild.' That mortality experience is very debilitating. Oh yes, it is good enough to get the young going, but just barely. As we had indicated the life expectancy is perhaps 20 years. Much later, when we reach Man in his current epoch, when we can limit and isolate the causes of debilitation, and life expectancy gets to be a larger fraction of the life span, then it is relatively simple to balance the accounts.

But the issue is not a trivial one of 'accounting' for some obscure mathematical detail. Think what it does to the epigenetic value potential. What attitude could parents in a family have toward children whose chance of survival was nil, to each other when the expectancy for further life was slim? The answer has to involve both anxiety and detachment. (It is different for other animals, who do not have such a cognitive freedom of comprehension in their nervous systems. Grief may exist, but it is not far reaching, remembered, coupled indefinitely into all other behavior, Freudian.) The society, thus, in its values, simply could not carry forth with any sentiment toward its very few number of children, or older adults, except for a few walking memories on how to do things. (Social memory could be so transcribed, orally, for periods of the order of 10 generations. That therefore represented the coherence scale for such cultures, with speech but without written records of any extent. Remember they had symbols but no extensive written language.) One can understand, perhaps, the origins of the concepts of religion. If life had such an uncertain future, and if it could be associated with the disappearing quality of a spirit, of a moving wind, of a flickering flame, or a flickering memory (note that that men conceived of life, motion, and spirit in these metaphorical terms is only an assumption of ours - we think it fits Man's nervous system), then it was safer to attribute continuity to such movements, and spirits, and flames, and symbols than to the disappearing reality. A preserved magic symbol, finally a preserved religious symbol could preserve the spirit that has disappeared. We find the very writing of such language possessing a hint of the excitement and mysteries that it is supposed to encompass. Is this not a plausible way by which magico-religion was born? Also, is it the case that the old, facing the issue of death, have the greater compulsions to discover and propagate such mysteries? Do we wish to hang on to our life, and to those and that which we can possess? Is this particularly developed and a function of our nervous system with its great capability in dealing with abstraction? Hopefully we are indicating that it is still the parsimonious principles of physics, here the strategy of outlook for a command-control system that can make many branching decisions, which even reaches out to a totality of speculations that Man deals with.
Chapter Eight - The State of a Liquid

It is easy to be a gas. Confine a bunch of atomisms by the walls of a container, or by some very weak force system (we illustrated with one weak force of gravity at large size). Toss some energizing potential in - say radiation of the wall (or just vibrate the wall). The atomisms begin to bang around, among themselves and the confining wall. The energizing potential keeps them moving, it 'feeds' their internal parts (if they have any internal complexity). There you have it, a gas.

If you are the boss potential, exerting authority on your flock – cows, sheep, wheat (you may share your authority with other boss potentials, such as the sun), bacteria, men (you may be a prison keeper, or the company president who pays them with a monetary potential) – clearly you manage to keep your flock going basically just like that.

But how does it happen that matter condenses? In particular how does it happen that your atomisms can get into a liquid state? As a subtle point, it would seem much easier for them to clump, forming aggregates who don't move, a solid state.

It is true. The liquid state, in which atomisms clump (condense) but yet can continue to move on is an evanescent (quickly appearing and disappearing) state. So we have to tell you how that works. It is really at the basis of all bonding.

Believe it or not, the atomisms in a liquid really clump and bond loosely (in a group of about 20 - see how many neighboring peas or pills cluster around a central pea or pill in any container full of peas or pills), to form a temporary cell, chatter among each other, and then one breaks away and takes one step to continually reform all the clusters. A very crowded cocktail party, in fact, was exactly the proper place to study the movement. That is a liquid, a hopping Brownian motion. Boys-girls meet, boys-girls chatter, boys-girls move on.

Two questions: why did they bond, why did they move on? The basic motion was just like in the gas. Somehow, some place from a remote potential, the whole ensemble is receiving energy (from the walls; from inside stores, intermittently recharged from outside depots). That energy is partitioned among internal moving parts. The atomisms keep moving and banging into each other. But when that ‘thermalizing’ energy is reduced, they keep banging but their range keeps shrinking. They seek out arrangement that can reduce their motional energy. How? By sharing it in certain common motions. Believe it or not, that is the basis for binding. Bonding takes place from a shared perception of how to serve common needs. Morality? Philosophy?

No, physics. There is no altruism in the shared perception of having to make do in common, only an insufficiency of resources. Perception is an integrative sensory construct, one that can be held both by atoms, by people, and by stars.

So with insufficient energy to make those long free 'escape' flights to and among distant cousins, it is less costly (in energy) to chatter near home. That is why you don't try to go charging through a cocktail party, or a crowded subway (except in dire emergency). Instead you 'slowly' (diffusively) work your way through the crowd. All of the chattering is necessary; the necessary curtailed form of those long flights, before you can find a very small opening and move on. In a liquid, in which there are about 20 neighbors, commonly an atomism has to conduct up to perhaps 100 such chatters before it can take one such step movement.

We have told you, now, about the movement. We have not really told you about the bonding. So now we will try that.

In particular, we will tell you how the first (one or more independent) bondings take place. But first we have to set the scene. So we imagine a container filled with gas, in which the atomisms are bouncing on and among each other and the walls, all supplied from the wall.
temperature-radiation and vibration. We will keep taking down the energy level in the walls (we will reduce its temperature). What will happen? Experimentally with sufficiently reduced temperature, the gas will condense to liquid, and ultimately to solid. Do you want to see it? Fill a jar with water, heat to boiling, let the steam force any air out, and then cap the jar. As it cools, the gaseous steam (water vapor) will condense back to water. Cool it further in the refrigerator, and the water will turn to ice. The process happens in your pressure cooker, but you cannot watch the interior.

You don't have to do it with water. You can do it just with the air in the jar, but to make the air liquid requires a very much lower temperature. Some place or other someone (a science fair, television?) will show you liquid air. Such liquefied gases are used by the ton in the space program. (Always remember that water is one of the easiest examples of a liquefied gas but your family is another. Why else do you come home every evening?)

As we cooled the gas, why did the first droplets of liquid condense? Why does condensed matter form? Let us look first at the prior and still existing gas form. What is going on in the gas is sustained fluctuations. The motion of diffusion, the Brownian motion, the boy-girl story, is called a motion of fluctuation - dissipation. What kind of fluctuations are going on? They are collisions. Most often (almost always) they are collisions between pairs. But occasionally 3, 4, 5, etc., collide together. Commonly? No. Rarely. But there are even ingathering collisions of 20. Does that kind of fluctuation make a liquid droplet? No. Let us provide a more fundamental metaphor. Two parents (now different families) have children that they would like to see bond, so a 'blind' date is set up. The boy-girl meet, nothing happens. Two ships passed in the night. (The cynical might say, "Lock them up in a room for a week, see what happens." Be that as it may.) They likely acted on each other - in physics exhibited some sort of exchange force – but no bonding. What does it take for bonding, whether chemical pairing, or phase change condensation? It requires a giving up of bonding energy by the pair. They must mutually lose some energy and then share that loss. That is a very fancy process. We can show that it requires what we said before, two or more force systems acting on the common field to create a new dynamic flow form. The only difference is that now the flow forms are internal to the new condensing matter system. It is complicated.

As the temperature is reduced, the likelihood of multiple collisions increases because the atomisms no longer have the energy content to bound out in their normal highly energetic motional flights (their kinetic energy is reduced). A temperature is finally reached in which some collection of '20' atomisms in the ensemble stick together. They moved in fast, at high kinetic energy, but that common energy was dissipated - carried off and radiated - from the cooperative cell. They cannot move out, away, at the same speed that they moved in.

That droplet evaporates, but more slowly than it forms, and then other such cells form and evaporate (diffusive). That game begins to transfer from region to region. It illustrates a field that is becoming extensively unstable. 'Precipitations' do not take place at one place, but at many centers. As we will indicate later, it is such multicenter instability that one finds in the start-up of cities and civilizations. There is little meaning to the very 'first' such condensing fluctuation (not that there wasn't a first), but it indicates that the field is unstable, ripe for a new form. The birth of ideas within the electrohydrodynamics of the brain has exactly the same character. The appearance of invention of new ideas in the history of people has that character. This the kind of relevant answer rather than common fruitless arguments of linear versus multiple center diffusion in social processes. When a field is basically unstable (we refer to a low margin of stability), then little energy differences are required to trigger new instabilities. The entire
nervous system net is like that. When the process goes over the threshold, more fully, one gets
the kinds of instability seen in epilepsy, in Parkinsonian tremor; or in society in waves of anger,
or common patriotic fervor.

And so when temperature is lowered further, more and more such nucleating
condensations take place. It is only when gravity also acts that the condensation particles
precipitate, join together and form a whole body of liquid. With gravity balanced, condensed
cells are to be found in clouds, a system that we touched on earlier.

The two force systems that permitted the cells to form locally? One, a very weak
electrostatic force (van der Waal forces) that acted between the atomisms; the second, the force
that led to electromagnetic radiation and thus heat energy conduction from the group. But that is
detailed physics.

Why then the more restrained, solid state? We will save that story for another chapter.
Chapter Nine - Man in Modern Society; Part II

So, in terms of the previous chapter, one can see that near liquid-like behavior of human groups of hunter-gatherers. Small not quite isolated cultures, sparsely filling up various land masses for that long middle Paleolithic period, engaged in evaporation and condensation. Such groups were tied intimately to the potentials of the land. As a whole, these land masses made up an ecological habitat, with each group tied to its niche. But like a near ideal gas, or a near ideal liquid solution, a similar process holds true for every other species, although all their habitats weren't necessarily as extensive as Man's. Niches for non-similar species, like a mixture of gases or liquids, can exist in the same habitat.

Man's range is very nicely pictured in Prideaux's Cro-Magnon Man, and Hawkes' The Atlas of Modern Man (try them; you will like them. The Times Atlas of World History is another very handsome volume of picture stories. While these books are all handsome books, they do not suggest the dynamics of history over the ecological-geographic fields. Only Darlington's The Evolution of Man and Society does so to some extent; or Braudel's The Mediterranean somewhat more).

If other species can exist with little or no change for periods as long as a million years, why should there be changes in Man? As we indicated, the capability of transmitting an epigenetic heritage of tools seems certainly to have been involved in putting pressure on genetic selection (genetic pool always contains a large number of recessive mutations, so that environmental factors can always put selection pressure. It is not unusual that environmental change that brings about genetic change then can produce new modes of behavior that will result in further pressure for changes. The technological rate potential opened up a new path of change with a great number of branching potentials. A note on this process is in order.

What made life possible as we shall discuss later, is the discovery of chemical paths that could produce many branching chains, the kind of unstable process that is referred to energetically as an explosion. It is not unusual, it happens in many systems. The technological rate path was one such example.

So examine the evolution of tools for the past 2-3 million years, from hominid ancestors, through Homo ancestors to modern man (his middle Paleolithic phase). Look at all of his cultural use of artifacts. Ask the question - where is it going?

Obviously, one way it was going was to diffuse and fill up all earth spaces that weren't too inhospitable to provide the potentials. Maps easily show that. Water barriers delayed but did not hold back too long. Witness the crossing to Australia. Note the diffusive crossings, across the land bridge to the Americas from Siberia during one or more cold spells. So what next, what next?

You have your choice - a gradual change, a sudden change, one cause, a number of causes. But in any case, a phase change took place. Man precipitated in place. Why? Because it really required an overall lower energetics.

Many people have interpreted that notion to mean that Man had to work harder after than before, but since they could show that life was easier before, it couldn't have been a matter of energetics. That is a bad analysis. The fact is that the potential per unit individual was less afterward, and so a much larger population could be supported.

Remember, what had to happen was that a greater population has to be supported. There was no room to swarm and outbreed to many more areas. Growth in place had to take place.
Now most species just become stagnant under those conditions. Instead Man was driven by his few new potentials. Men still had room and modes to find solutions. So settlement in place, based on agriculture.

There is no way, at present without a great deal of minutely detailed study to follow exactly the field events and circumstances by which Man made the phase transition from fluid hunter-gatherer to settled in place agriculturist. Loosely speaking we would tell the story as follows: Modern Man had diffused over almost all parts of the temperate and tropical world by 30,000 years ago, even into the Americas by 15,000 years ago. Man's hominid ancestors had undergone a much earlier diffusion over most similar parts of the world starting from African savannas. These upright tool using animals had no great difficulty in adapting such a hunting-gathering style over a great number of habitats.

But there was no reason that any such animal should not be entrained by useful potentials. The exposure of a variety of such animals and plants to a number of repetitive ice ages most certainly influenced their movements. Shortages or excesses of food most certainly have influenced migrations. The northern Eurasian steppes and tundra in the last ice age certainly furnished modern man with a driving potential front. The northman evidence in Europe, of modern man following enormous herds of reindeer as nomads (as the American Indian, much later, followed the bison, or the Asian Mongol herds of horses) lends ample testimony to the thesis. (See, for example, Froncek's The Northmen.) Thus the annual fluctuations of the melting glacial front, with a relatively dry climate, served very much the kind of later function that the annual flooding of the Nile furnished Man along a river. Here the 'water front' was fed from a glacial 'sea.' Thus plants such as grasses followed the water supply, grazers the plants, predators the grazers, and Man the hunter-gatherer followed them all. Thus Man was domesticated.

In other regions, Man followed other styles of annual life. We want to stress, not any exceptional intelligence of these Northmen, but the environmental pressure on them to fit their life style to what was available.

But the ice age came to an end. The glaciers retreated to their current positions. Mountains and land were gouged; as maps will show, an extensive system of river valleys developed in these new upper temperate latitudes. The plants and animals dispersed. Many, such as grasses, had been evolved and advantaged by their glacial experience (just as Man was) and they adapted to the new river valleys. Grazers were also advantaged, and thus grain and grazers found suitable niches in these river valleys. Hunter-gatherer Man entrained and transformed by his epigenetic potential into gatherer-cultivator. We cannot insist on any precise time scale, but starting perhaps 15,000 years ago and fairly complete by 10,000 years ago with the end of the ice age and a rising ramp in annual temperature, northern man gradually became more sedentary. He began to bond and lock more into place with respect to fixed river water supply, toward the gathering and cultivation of the grazing grasses (wheat and barley), and toward the hunting and herding of domesticable animals. (What is a domesticable animal? One whose nervous system permits a matching of modes of action between the domesticating and the domesticated species, as leader and follower. It fits or can be made to fit the former's life style.) These animals were pig, sheep and goat.

Evidence for an increasing degree of settlement is found. The transition is often referred to as the Mesolithic Age. That period, in its first appearance in the Near Eastern regions, is marked as being as narrow as perhaps 12,000 to 10,000 years ago. The transition ushers in a 'final' transition to the Neolithic Age that begins in those regions perhaps 10,000 years ago.
The transition is not so much to a 'new' style of tools ('Neolithic') as it is to a new style of life. Thus the transformation in tools largely reflects that new style of life.

Our basic thesis is that one form of settlement or another had to take place for stability reasons (to support higher population densities, but necessarily starting first in some localities), and that the end of the ice age furnished the sharpest cause for precipitation in one region, and thus started the first localization of an agricultural revolution. In turn, partly independent (as in the Americas) and partly diffusively connected (witness the diffusive spread of agriculture from the Near East throughout Europe from about 8,000 years ago), that kind of precipitation took place over the world. The concomitant Neolithic Revolution in tools followed. Metallurgy, as an even more advanced form of tool making, and pottery, as a 'tool' means for making containers then also diffused around the world.

This entire initiating period, say 12,000 to 8,000 years ago, served as a transition period to learn settled forms of agricultures. In many parts of the world, subsequently, agricultural villages formed as a sedentary way of life fulfilling the needs of small cultures they even still exist, in parts of the world. But even that form was not fully stable. An even more energy conservative form (or energy intensive form) was needed. That was needed to permit even higher population densities to grow.

It is interesting that in the same general region that agricultural settlements likely first started, the regions to the east of the Mediterranean, known as Anatolia and Armenia, constellations of interacting settlements first started up.

We share with Jane Jacobs, the urbanologist, the notion that a number of urban centers sprung up almost simultaneously in some specific regions and began to conduct trade among themselves. That was the beginning of modern ecumenical civilizations as we know them in modern times. This was an advance over the isolated agricultural village. The energetics (per person) are lower. (That sort of statement will provoke argument. What it means is that a smaller region can support an individual, by cooperative effort among action modalities, than if persons did not go trade and share. The optimization in energy, action modes, materials permits that kind of operation. Of course the 'land' or whatever environmental potentials are drawn upon, is raped, but the question or hope always is whether the process can be conducted by very rapid turnover of 'renewable' resources, rather than expendable potentials. Witness how we raise chickens now by intensive 'factory' methods.) Various centers could specialize in particular functions, and by trade, as a convective process, balance their needs.

So here once again, we are up to the physical conservations. What conservations did such constellations operate with? Again - materials, energetics, population, action modes. And in order to carry on the convection in trade, they had to invent a common abstract measure for what they convected in trade. That measure was value-in-trade.

Why did they need it? Because physically, one sees two new kinds of stabilizing forms emergent. One was the condensed and precipitated urban settlement. This was a substitute for the more fluid hunter-gatherer culture. Identity and 'loyalty' of the bonded families had to be to that center. Others were outsiders. The second form was the constellation of such centers, bound as an 'ecumene.' (An ecumene consists of all those cultures whose command-control leadership tolerated frequent convective intercourse. In time such relations, internal to the groups, and external between the groups would be 'politically' governed, by band, formal epigenetic codes. Earlier, only family, band, and clan codes existed in earlier near isolated cultures.) Other center adherents were outsiders, who were permitted trading privileges. Some abstract exchange element had to exist to permit transfers. Thus value-in-trade.
The two earliest trading ecumenes that are known were found in Anatolia and Armenia. They each consist of a group of about 20 or so settlements that formed an extensive spatial cluster (see Hamblin The First Cities, or Melleart’s Earliest Civilizations of the Near East). They were functioning in place in a period approximately 7,000 to 9,000 years ago. All of their 'history' is prehistory. There are no names, no events, only artifacts. But radioactive tracers have been able to prove some of the material in trade and that in fact where the material originated. Such a traced material was the tool material, obsidian. Its virtue is its extremely sharp and hard cutting edge as a tool.

The trading ecumene had a history of development and interconnection that we are not aware of in much detail of this early stage. But it is clear than settlements interacted, grew and declined, fought; it was clear that an evolution of technical complexity, by virtue of that potential was taking place. Agricultural methods and tools, more and more specialized stone tools, metallurgy - first with copper and much later with iron, the bow and arrow, the twirling bolo, pottery, domestication of more animals - such as the dog, changes in the style and mode of building home shelter all took place. The ability to begin to trace other independent evolution of these techniques, or diffusion from these times is now in existence.

A capsule summary of some developments that can provide the reader with a sense of the uniform scale of development of technology, the essential uniformity of the technological rate, is the following: The listings can give him a sense of participation, in that they are things that he could have or might have done, given about the same time scale:

10,000-8,000 ybp (years before present) - precipitation toward settlement, primitive housing (e.g., by reeds); perhaps some domestication beginning, intensive food gathering with some early food production, further specialization of hunting and making tools (e.g., for hunting small speedy animals, microliths).

8,000-6,000 ybp - growth of housing structures (reed, clay, mud, some stone) that are found layer upon layer; certain domestication, diversification of materials for tools (bone, wood, fibers, ground and polished stone, unbaked clay, sea shells, obsidian, bitumen), vehicles (sleds, canoes), weapons (bows and arrows), cultivation of wild wheat and barley, food preparation (mortar and pestle, ovens, stone bowls), diversification of artisans, vessels (unbaked clay, stone).


4,000-2000 ybp - Cities, kings, empires, metal. Elaborate large scale structures. Written language. Slavery. Well defined social structure including artisans, etc. Extensive bureaucracy. Well defined social rhythm of war.

2,000-0 ybp - Moral codes elaborated; simpler ones adopted. Elaboration of all forms of government. Ritualization of civilizational forms. Money in value. Monotheistic ideals.


More abstractly, one might say

pre 10,000 ybp - Hunt like an animal, but already with tools and other abstractions. (At present we are not trying to restate pre-Neolithic development).
10,000-8,000 ybp - Logical cause and effect. Planting and cultivation of seeds leads to plant growth.

8,000-6,000 ybp - Technological implications of the cause and effect of food cultivation (instead of hunting) - houses, vessels, domestication, vehicles, weapons, diversification of materials, diversification of artisan functions (i.e., the full range of extensions of body function)

6,000-4,000 ybp - Societal implications of the cause and effect of food cultivation - village, diversification of structures, social diversification of domestication, abstract value in exchange (trade), abstraction in engineering and art forms (i.e., the full range of extensions, both external and internal of the mind and body to societal structures)

4,000-2,000 ybp - Implications of societal organization - kings, empires, slaves, warfare. Evolution of social forms - from settlements, to cities, to city-states, to empires; all artisan forms, and bureaucratic forms. Abstraction of written symbolic language

2,000-0 ybp - The metrication of behavior - examples? Arithmetic money, codes. The numerical or enumerative properties of mind.

0-2,000 years in future (?) - The geometric or field properties of including discovery of the nature of its internal dramas.

2,000-4,000 (?) - The dynamic character of man's interior. Human command-control. Can man socially deal with his destiny?

The fact that a few trading ecumenes may have formed as early as 10,000-8,000 years ago does not mean that they are a preferred stable social form that will 'immediately' sweep the world. It does mean that, if our physics and physical conjectures are right, other such constellations may start up - independently or diffusively. As we showed in the gas case, condensation does not have to take place everywhere at once. More than one phase can and will coexist, in fact as the gas, liquid, and solid. Many other phase components of different materials may be found in a phase diagram. That is what chemical metallurgists, for example, are commonly involved with.

So what kind of 'motional' states did Man find himself, even if there was a beginning pressure to precipitate in place? Suppose, we were to take a snapshot around the world at say 7,000 years ago (it is still very difficult to derive clear compelling records with any precision closer than give or take a thousand years - so while it would be nice to have good stories to tell with large inventories of examples for each 2,000 year period, say 16-14,000; 14-12,000; 12-10,000; 10-8,000; 8-6,000 years ago, the records are still too spotty). In tropical climes, and many other regions we would still find hunter-gatherers. In many of the northern temperate latitudes, for example, well documented across Europe one would find the existence of many essentially independent agricultural village settlements. There are a few agriculture settlements (examples? Karim, Shahir, Jarmo, Jericho) known to have existed as early as 12,000 to 10,000 years ago is no measure of the extent of the spread of agriculture, only of its possible beginnings. More to the point is the documented diffusion (of people, it is now known, from the genetic record, rather than simply the diffusion of the action mode) of agriculture across Europe from about 8,000 to about 5,000 years ago. (See Cavalli-Sforza "The Genetics of Human Populations," Scientific American, September, 1974.)

So all of these forms of social organization could coexist - for a while. (How long is a while? Certainly 5,000 years, more like 10,000 years. The last hunter-gatherers are finally disappearing. Why? Because settled people - call them governments if you will, but it really has nothing to do with governments - need the room. Agricultural villages? Note that they still can exist today, but only in 'remote' and 'ill-suited' areas. Areas are ill-suited because of the local
potentials of climate - too hot, too cold - sparse geography-ecology, or too lush (e.g., tropical forest) and thereby too fragile an ecology to withstand penetration). So the hunter-gatherer is gone (within the next 0.1 of a millennium). Sparse numbers of near isolated agricultural villages still exist. The stable form became the trading ecumene. That form has been in transition, taking over most of the land surfaces of the earth from its start-up 10,000-8,000 ybp to its explosive historical 'beginnings' in the city-states of the Tigris-Euphrates valley and then the Egyptian Nile, the Indian Indus valley, the Chinese Po, the later Meso-American start-ups over the period 7,000-5,000 ybp, until it took on the beginning shape of modern forms 4,000 ybp in the first empires. The earth as a whole single ecumene has only closed 'recently,' not before a few hundred years ago. Largely now society operates with a commonality of agriculture, urban centers, 'political' form of command-control by local codes in polities (e.g., city-states or nations), local and long distance trade, alternation between trade and warfare to equalize flows and potentials, and a loose interpolity (international) code of action modes.

The operative potentials? As we said before – climate, geography-ecology (these supply temperature, materials, and free energy), the genetic potential (this supplies population), the epigenetic potential (this supplies meaning of how to do things, strategies for conducting the chain of action modes, as well as a memory of technology), and the technological rate potential. Loosely speaking, the changing technological rate potential is what drives the history of changing and evolving style of life and political form. That is a Marxian concept, but we do not consider it any more than a strategic rule for development, not an inexorable law.

The major outcome of that form of social evolution is its effect on distribution, that is on the storage of the various fluxes - of materials, energy, action modes, people, value-in-trade.

Note that all other living species, including Man as hunter-gatherer, do not think largely in terms of possessions. Many animals store - e.g., they have caches for winter deficits, or they store food within their bodies. Man, as hunter-gatherer, began a modest process of accumulation out of his epigenetic heritage, beyond food, of tools, clothing, and later of shelter. The Marxian theses is that ownership of the tools of production is the major drive in the form of Man's socialization. We prefer to see process that fixed settlement permitted storage in place. Of what? Of the necessities. The agricultural village could grow and persist with storage. One senses, the immediate and symbiotic relation between agriculture and the villagers. Cooperation, for the common welfare (to satisfy needs) would be a necessity. The strategic role of a command-control leader was accented. Thus a conversion in role from hunter leader to village leader was an obvious step. The primate brain encouraged at least pack leadership, the human brain encouraged it on the basis of an epigenetic heritage, experience, and some coordinative skill ('wisdom'? cunning?).

The size would remain comparable to hunter-gatherer band size, still 25 to a few hundred. Population support in such a number of family bands was quite feasible. If in pre-Neolithic hunter-gatherer days, population growth of perhaps percents per century (e.g., less than one additional person, above turnover, per generation) would be tolerated, now some modest population growth could be permitted.

At this point it is of utility to know the law of population growth. Population grows by the Malthusian law, no other, in proportion to the existing population. But it is the coefficient of proportionality which governs the growth. That coefficient is the birth rate less the death rate. The death rate may be fixed by the existing practice of life style (sanitation and all that), but the birth rate is more 'freely' chosen. Thus the real law of population growth can be expressed as follows: Population changes by the difference in rate at which the breeding population 'chooses'
to have children 'now,' as compared to the weighted average up to about three generations 'ago.'
(The problem in pre-Neolithic times was that the connection to the 'ago' was so tenuous. The
death rate was so large that it appeared that each new generation had almost 'forgotten' what
drives had existed before. Thus bare survival and very slow growth and outbreeding was the
format.)

With fixed agricultural settlement, a significant gain in population growth could be
encouraged. This produced an increasing growth of 'population pressure,' a pressure to expand
groups. Thus agricultural settlements could bud off and diffuse, at rates like one mile per year
settlement range per generation.

Clearly the potentials and fluxes (and a knowledge of the epigenetic heritages of the time)
would permit a reader to participate in or design (if possessed of some leadership drive) such an
agricultural village life today. It might take him (or her) a generation or two to master existing
or the feasible technology. European settlers in the Americas faced such questions as recent as
the 16th Century. European Kibbutzim faced such a problem in Israel in the 20th Century. So
the design and operation, by the laws of physics, are not unusual - as to size, number, separation,
required potentials, replication rate, storage, likely fluctuations. Form of government? That
depends mostly on the leader, and the potentials. Value-in-trade? Not required if the village is
self-sufficient. It is only when there are outside needs that trade becomes significant.

Or defense. If outsiders are attracted and their ingathering becomes too aggressive. then
some mutual arrangements are needed with other settlements. Thus there are a handful of
pressing reasons for near simultaneous growth and evolution of other neighboring settlements
and intercourse. Then value-in-trade emerges. As that emerges there arises three kinds of
population - those attached to the urban population centers, those who are spread out or isolated
as fixed 'rural' agriculturists, those who are in non-fixed motion. And within the population
centers, there arise a new form of elite leaders.

These molecularity forms create the field dynamics of the trading ecumenical society.
People move from region to region. That is a process of people diffusion. There are clearly
perceived differential reasons for the motion. Once again we are back to the cocktail party
metaphor. But also energy and materials are stored and diffused. And value-in-trade. An apt
definition of a polity is that region in which the diffusion rate differs for the inside and the
outside member of the polity. Thus any complex atomism really represents a 'polity.' Its
surrounding wall or 'barrier' is the barrier to diffusion between inside parts and outside. Social
organization is built on the same concept. As in other than simple gases, the diffusion rates for
different conservations differ (heat conduction, viscosity, and mass diffusion have essentially the
same rate for a simple gas; they differ for a liquid or any other complex association. It is the
same case in human societies).

That differential diffusion piles up some conservations for some human atomisms much
more greater than for others, once trading ecumenes are established. What one considered rules
of economics begin. If there is a demand of an essential needed 'good' (material, energy, service,
action, or needed population) it is supplied, etc. But the convection need no longer be uniform,
homogeneous. Some centers or individuals have access to higher potentials. The division of
potentials becomes private. ‘I own’ becomes a key. So, by differential fluxes, 'wealth'
accumulates. Of what? Of material, of energy, of value-in-trade, of epigenetic potential, of tools
- just knowing when to plant or how to treat or what to do becomes a material or mode in flux.
From knowledgeable elder or competent hunter, to Shaman, to priest, warrior, ruler, successful
farmer, or storer, or investor becomes an order of transformation of leadership. (A beautiful set
of pictures, depicting the changes, may be found in National Geographics' *Everyday Life of Ancient Times*.

Can you as charismatic leader, design a trading ecumene? We believe so. You can estimate the size of the territory, the number of settlements their size, given earth and Man potentials, the activity modes, the convection of goods, people, and services, the technology, the emergent elites the frequency of wars, etc. We won't bother to detail all the internal bureaucratic forms that one required. You can imagine them. Will you do as well (or badly) as historical leaders? Certainly. Perhaps now you may also understand our physical inference. In about 20 generations of 'your' leadership (not just you, but 20 more, your friends?, your relatives?), in about that time you will have succeeded in building up that civilization and tearing it down. Why? Because the high energetic mode that you force on that convective system, regardless of the political system you elect, becomes mismatched. The chain of leaders develop an error rate which ultimately becomes destructive because they are concerned more with their own internal ego modes than the society’s. That is what made them high energetic elites. Unfortunately, they always have to begin to treat the rest of the people as their flock, more cynically as domesticated cattle (or when even more unfeeling, as their slaves).

Can that be prevented? Not with this biological species. It is built into the epigenetic potential, a character of the human command-control nervous system. Perhaps it can be outbred in 1,000 generations, but we have doubts.

Are the elites necessary? What do they do? Yes. (Are bureaucrats necessary? Yes.) They are required to accept the organizing leadership to keep the high production population machine going. The population pressure forces them into existence. They charge for the service. They take a cut off the top of about half the productivity of a band of perhaps 25 to 50 people. They make up and can only make up a small percent of the populace. The populace can 'easily' carry the burden, because the elite can oversee an increase in the productivity of the potentials. If you don’t pay them, you have to do it yourself. And as a group, you cannot and will not.

All this is said independent of the political (or economic) form of government - whether capitalism, or socialism, or communism, or feudalism, or fascism, or democracy, or anarchy. Man, you create and have to create the chains of your own binding. What might your biological successor do? That is a different story.

Do not love the idea, or hate it, or reject it. See what you can do with your understanding of the idea.
Chapter Ten - The Highly Ordered Solid State

So we cool our liquid off even more, and it turns to a solid, a lump. Dull, isn't it? Not quite. Perhaps it 'only' made a solidified lava sheet, a rock, a lump of steel, of coal, of ice, but it also made the whole earth, it made parts of our body, it makes the tools, structures, vehicles, utensils, buildings, machines that we use. What really goes on in a solid?

Obviously what happened is that the atoms and molecules in the frozen out solid field stopped moving about. Completely? No. They only stopped moving relative to each other. Instead they become 'springy,' they are now bound as springs. They can vibrate (or jitter) in place. While they now may exhibit a lot of patterning, a patterning that is referred to as crystalline or amorphous, yet close packed, understanding their energetics is somewhat simple. The repetitiveness of the structure, lattice-like, or near lattice-like (all neighbors closely packed, similar to a liquid, but with somewhat more specialized arrays and no liquid freedom of movement) makes them behave fairly much like a simple system. We can, for example, estimate the specific heat by which it equipartitions internal energy. Each lattice point can move in three directions. That is three degrees of freedom. These are point particle degrees of freedom. Since the lattice points are not occupied by point atomisms, for example imagine them to be sphere-like, one finds three degrees of rotational freedom. Such a body can be angularly tilted around three independent axes, two axes through the equator, one axis through the poles. That makes six degrees of freedom in all. But, as a subtle piece of physics, that would be true for a free body. A body that is restrained by springs has two degrees of freedom for each motional degree of freedom. The subtle piece of physics was that there are both displacement, and momentum (velocity) degrees of freedom. Energy goes into both. Thus in toto, there are twelve degrees of freedom. Compared to a simple gas consisting of point atomisms (three degrees of freedom), the solid can absorb four times as much energy with temperature or heat. Simple? True. Except at low temperature.

The point to telling this small story is that it leaves the impression that a great deal of the solid state story is dull, even if it makes pretty crystalline pictures. But that story does not get to all of the marvels that may still be found in that state. So we have to probe further in the dynamics.

So far the solid looks like a more internally organized gas, as far as its atomisms are concerned. Each one seems to be on its own, we still do not see much 'sharing' at this temperature (or temperature range, one beginning from the first freezing on down). We do not see much happening, except that a solid can get hot and absorb heat and transmit vibrations by the internal springs, and resist external forces (which permits us to use solids to support loads - stresses - and thus make up mechanical structures).

But let us cool a solid down to very low temperatures. At a critical temperature for each substance, we find experimentally that the specific heat (a count of the number of degrees of atomistic freedom) begins to decrease. It gets lower and lower and approaches zero. It was a remarkable tour de force of Einstein's to loosely explain the reason. The suspicions we cast was correct. The assembly could not really afford the common independent motion of each atomism. They really had to 'double' (triple, multiply) up their energy. So our problem is to figure out what really are the atomistic units, because really there is more binding in the solid state than is taken care of by our simple statement that each lattice point represented an independent atomism.

Note that in the solid state we have no conservations other than mass, momentum and energy, and the only potential we have is the temperature-radiation equilibrium. But we slipped in a ringer when we slipped in our tale of 'springs.' The image we tried to present was that of a
regular array of say heavy steel balls welded each to each other by say sets of three springs so that you have highly connected bed of balls and springs. Except that the springs in the solid are not mechanical springs, they arise from electrical forces and then tend to act in unison.

So as we sweep energy into this highly organized and cooperatively sharing system, we note the paradoxes. It has many degrees of freedom, but they are 'frozen out.' As warming energy is absorbed they are released. While there does not seem to be much action, they are cooperatively linked in many ways, and do exchange a great deal. The binding process, as identified by Einstein and later formalized by Debye, is represented by a continuous exchange of phonons. A phonon is an 'acoustic'-mechanical wave, which really is propagated by an electromagnetic action, which continually runs through the solid and represents the exchange binding (and communication) throughout the solid. In fact there is an extensive spectrum of such phonons. That notion constitutes the theory of the solid state. The phonons represent the basis, as an exchange force, for the creation of the solid state springs, which make the solid such a highly cooperative ensemble.

It is very much like asking what binds 'low temperature' people together. In a similar fashion, there are 'phonon-like springs,' also electromagnetic in origin (they are the electrohydrodynamic forces that organize flow streams in the networks of the nervous system and the neuro-endocrine networks), which provide the exchange force binding system (and communicational system). They have an extensive spectrum. They are not quite as dummy-like as in the solid (although one might note the Greek metaphor about the crystalline ball nature of the universe, and the 'music of the spheres.' Many people like the metaphor that the universe and all in it sings). But that is related to the fact that the life system mixes up the character of both solid, liquid, and intermediate gel state.

What does a solid and its interactional phonon system 'do'? Very little except survive and resist forces of dissolution. Of course some solids 'rust' and do become modified, or degraded in their ability to persist.

It is that release of internal degrees of freedom (not 'melting' in form, only release in function) that represents the Einstein-Debye theory of the solid state, in which the number of degrees of freedom increase as temperature is raised from absolute zero to the critical Debye temperature. Then the atomisms, solid, have their apparently rather free and rich number of twelve degrees of freedom. Then do not have to share and freeze out their actions.

As more energy is poured into the system, it heats up, until it reaches a temperature that those 'spring' bonds break. Energy is absorbed internally to break the bonds (with no change in temperature) and the solid melts. Now the liquid heats up, with rising temperature, until it boils (bonds break without a change in temperature) and we have a gas. Heat the gas further and its temperature rises until a critical temperature is reached when - as in the star - its atomisms are stripped by further energy absorption, and new degrees of freedom are released. All the changes that take place are either phase changes (from solid to liquid to gas) or chemical changes (in which the atomisms break specific bonds, with new well-defined fragment atomisms appearing). Each such process absorbs energy that breaks the bond. That process may be referred to as requiring an activation energy, each given a special physical or chemical name. In this prototype line of processes, we have not identified the many additional chemical steps that may have also occurred. Additional transformations in the solid, liquid, or gaseous state may have taken place as chemical change. The absorption processes (specific heat) between the abrupt breaking of bonds, was only involved in increasing the motional or kinetic energy associated with the bound degrees of freedom within or internal to atomisms.
Hopefully, this gives you some primitive idea of how the states of matter are organized and their internal complexity. The solid state (a lump of rock) may appear dull on the outside, but internally it has interesting capabilities.

We said that the solid state can survive, and it can resist external forces (remember we get our idea of springiness from solids. We make our springs from solids). So we ought to tell something about that process. A rock sitting on the moon or Mars, or a small satellite in space, doing nothing for billions of years does not tend to strike us as the most important member of an active universal system, even if it perhaps contributes to the universal gravitational force. So we have to tell a little on how solids get involved in processes, and perhaps get out of play.

The springiness is the most important property that distinguishes a solid from other phases of matter. A liquid holds its shape. Its atomisms are quite huddled together (true also in the solid), but as we showed, they can move relative to each other. They diffuse by shear viscosity. A liquid (or gas) stirs. The solid, on the other hand, resists deforming to stress. A long time ago, Hooke expressed the mechanical law of the solid. The strain (deformation) is proportional to the stress (the unit force). Since this takes on many forms, we will illustrate some of the forms. Pull on a long wire. It stretches according to the pull. Twist the wire. Its angle of twist is according to the twisting force. Squeeze uniformly on a rubber ball. It deforms uniformly in accordance with the squeeze. Deflect a beam (e.g., press on the end of a ruler overhanging a table). It bends in proportion to the load.

What is happening inside the material? The outside forces are transmitted by the phonon springs to the atomisms. Remember that the atomisms cannot move from their relative position, as in a liquid, so the forces have to be brought to them. If there were no springs, their relative motions could not resist the forces. Pull on a bunch of sand particles and you will find no spring forces. They will not stay together. So the 'mechanical' springs must be real, even if we say they come from electrical forces.

But can you stretch the springs indefinitely? No. They break. Pull on the wire, it breaks. Pull on the stretchiest spring material known, rubber. It stretches much longer (for example, up to ten times its original length), but then it breaks. What is the nature of that process?

The solid state, as we described it, seemed to have completely new processes. Now we want to show that they were not completely new. So consider the local cell of atomisms, perhaps 20 odd neighbors in a liquid. Since the solid is also a crowded arrangement - its density is not very greatly different from the density of the liquid at melting – it also must have about that many neighboring atomisms around any central atomism (although the crystalline arrangement may be much fancier). When the gross elastic solid is deformed, by stretching, shearing, bending, twisting, obviously the local atomisms deform in their relative positions. Their springs cannot resist indefinitely. They may for a little, for small deformations. Such deformations can be considered 'linear.' Each unit of stress is accompanied by a unit change in strain, Hooke’s law, stress is proportional to strain. But ultimately a deformation is reached at which at least one atomism makes a giant step. It moves its own diameter; and perhaps another atomism moves into place, perhaps not. In either case, one recognizes that a motion very similar to a liquid motion has taken place. It is like a diffusion step. But, in the case of the solid, it is referred to as a dislocation. If the springy bonds do not break, then a motion of dislocations may take place without the material as a whole breaking apart.

That now begins to describe a little of what happens in a solid. There is a range of forces (or stresses) for which the elastic law holds - stress is proportional to strain. When a certain characteristic stress (or strain), is exceeded, depending on the material and its state, a process
which is basically a flow process takes place. The material 'yields.' You can see this very easily in chewing gum, or rubber, or textile fibers. It can be seen just as well in metals, but the changes are smaller. After you put on a large stress, the material flows. When you take the stress off, the material is elongated. Somewhat like a liquid, which would change its length under any force, a solid has changed its length.

And this process can be continued or repeated, until finally, no more atomisms reposition sufficiently and the solid breaks.

But if those springs only have that property of withstanding deformations in the near vicinity, there must be some more special characteristics to the local arrangement of atomisms. Their regular crystalline array cannot go on indefinitely. It must be confined to a neighborhood. In fact by the time you have created a regular array of perhaps 100 by 100 by 100 atomisms, there must be some irregularity - a dislocation. We have to put it the opposite way. The appearance of a yielding or flow process by the time you have stretched solids a few tenths of a percent or percents of its length, indicates that you do not have regular arrays inside indefinitely. The neighborhood has to change whenever you walk 100 atomisms. Their 'ethnicity' changes. That we state as the experimental fact. We haven't explained why it has to be yet.

So basically solids, even crystalline solids, are organized by crystallites, small neighborhoods of atomisms, which are 'cemented' together a little different from the crystallized regular neighbors. This is called the domain theory of solids. It accounts for the much more limited nature of solid breaking strengths. Materials do not stretch a hundred percent. It accounts for the flow properties of the stretch beyond an elastic limit. It accounts for the value of alloying material, atomisms which can be fitted at dislocations and modify the cementing ability.

Let us dwell on the latter. There is a rule, the Hume Rothery rule, which states that any atomism which is not mismatched in size by more than ten percent can fit into a dislocation and create a bonding alloy.

We do not insist that this is the absolute modeling metaphor for the nature of all human elites. But we will insist that the rules of bonding are simple; that most of the problem is one of matching and integrating the mismatched or incongruent, and that human elites, like alloying constituents, are not exception in any way except that they can grasp what has to be matched. Is it a matter of 'ten percent' differences, e.g., in activity, or what? Who knows. We are in process of trying to learn the rules.

Oh yes, why does rubber stretch ten fold (or other fibers relatively large amounts)? They are not made up of little spherical atomisms. They are made up of long crinkly atomistic molecules. When they cement, along their length, they can be stretched longer. The stretch is not between the atomisms along those fibrous molecules. The same thing is true for bending in a beam. The stretch along the beam fiber is not the direction of the deflection. All such materials are called small strain (stretch between bonds), large deflection (perpendicular to the bond) domains. When that stretch is taken out (for example, link the fibrous molecules all along their length, in a rubber by 'cross-linking'), the material behaves just like a spherical domain organized material.

Why the mismatch whereby a domain is only coherently organized for a finite region, e.g., 100 by 100 by 100 atomisms? The underlying reasons, in the end, are the same why civilizations can only last a finite time (e.g., 500 years), why people form limited bonded sizes relating to their limited ability to recognize and empathize with other people, etc. Coherence in a theory of order and disorder, by virtue of what creates fluctuation - dissipation processes, can only extend out so far, before incoherent fluctuations (dissipations) will take the structure down.
Gamow's favorite example was the issue of putting up a tower of blocks. Regardless of how carefully you tried to match the surfaces, there arises critical heights (or numbers of blocks) which will tumble. That is basically a mathematical physical stability problem. Greater capability comes from building up local structures, and more local structures, and letting them support each other, even if they are not perfectly matched to each other.

We have not told you specifically why the mismatch took place in the solid, even if we have suggested the general answer. It would not be more illuminating to say that when the chain process of precipitation or freezing took place in the melt, when the solid formed, that fluctuation - dissipation could not tolerate an indefinitely regular crystalline precipitation. Instead, much like human groups in an unstable field environment, they start their precipitation process from more than one center. In the melt, the same thing happens. When the precipitates meet, they quickly move to accommodate. Some active elite (or odd-ball) quickly steps forth and takes on the bonding role for the mismatch. Hume Rothery rule?

Of course, you may ask whether by great care, a dynamic process can be found for making more perfect and longer crystalline arrays than letting the material come helter-skelter out of the melt. You can try to lay down the array unit by unit (the tower of blocks again). Of course you will succeed in getting longer rows, higher towers. But when you apply any stress to your longer row, higher tower, you will find that much of that artificial gain in length was in naught. The material 'work hardens.' Much too long arrays are weak; they crumple and crack. And so you find yourself having returned a long way toward the more disarrayed arrays.

Purity of breed may sound good, but you do best with an optimal addition of mongrelization. This is true in genetic codes, in metal alloying, in social bonding. The underlying physical reasons are the same - stability. Unfortunately one must always remember - these alloying constituents, elites, act twice, once to strengthen the structure, and also to tear down the structure.
Chapter Eleven - Running an Urban Settlement

So we raise the problem, how does one (the prince) run a local liquid-plastic-solid array known as an urban settlement? It is the same problem facing the ruler of the earliest Sumerian city-states (we do not know enough about rulers of the earlier Anatolian-Armenian trading constellations to use them as examples) of 6,000 years ago, as it is of the mayor of any American city. Why is it a liquid-plastic-solid array? Because the atomisms are locked into place locally, and can basically only associate, vibrate and rotate. They communicate and bind by 'phonons' (their great variety of exchange elements, exchanged to satisfy needs). They are liquid-like because they do make rather large excursions relative to each other. (One should note that liquid droplets have a rather specific solid-like elastic property, known as its surface tension to confine the condensed droplet on a surface. With little or no surface tension, the droplet creeps and runs like a liquid. Human settlements have that kind of surface binding force too.) They are plastic, because their motions do exceed elastic limits. They move like a liquid, diffusing; they move like a solid, by discrete dislocations. All of the internal action complexity does not change the external material characteristics. Take motion pictures, or lapse time photography for an urban settlement, at a scale that atomistic motion can be observed and you will see the motion and its similarity. You do not have to know what is going on in the minds to interpret the motions. (Of course, it does not hurt. You can sort out the internal details that much easier.)

So what does happen? In the main there is a factory day, tied to the day-night rotation of the earth. More subtly there is a longer factory day, tied to the yearly revolution of the earth around the sun, and the dependence of the ecological cycle on that process of making seasons. Still more subtly, there is the factory day of the process at the reproduction cycle, generation by generation. Clearly, in bacteria, we had to average our many such generation cycles before equilibrium was reached. Minimally among such process time scales, the human atomism in the settlement survives, persists in doing his thing. For what purpose? To fulfill his basic needs, his conservations, so that he can survive. That is all. All the rest, to give life a quality, lies inside, lies in the contrast between what is perceived out there and the detailed content of the epigenetic heritage. Man, with an epigenetic value system, can think that way. Other animals, we doubt, have the capability.

Not that an animal cannot be depressed by the perception of his external milieu and his memories. Chain a dog or cat, or horse, confine it or abuse it in ways contrary to those chosen freely by its command-control system, and you can find anger, depression (despair? perhaps that is going too far). But, as far as we can tell, we sense or perceive no long term epigenetic heritage, of long term expectations and many many hidden variable comparisons. The coherence there is shorter.

A good point from which to start our sermon is somewhere in between the ancient Sumerian rulers outlook and the candidate for mayor in the election. So we quote an observer's remarks in the 12th Century.

"As early as the middle of the twelfth century the German historian Otto of Freising recognized that a new and remarkable form of social and political organization had arisen in, Northern Italy. One peculiarity he noted was that Italian society had apparently ceased to be feudal in character. He found that 'practically the entire land is divided among the cities' and that 'scarcely any noble or great man can be found in all the surrounding territory who does not acknowledge the authority of his city'… The other development he observed - which struck him as even more subversive - was that the cities had evolved a form of political life entirely at odds with the prevailing assumption that hereditary monarchy constituted the only sound form of
government. They had become 'so desirous of liberty' that they had turned themselves into independent Republics, each governed 'by the will of consuls rather than rulers', whom they 'changed almost every year' in order to ensure that their 'lust for power' was controlled and the freedom of the people maintained…

The earliest known case of an Italian city electing such a consular form of government occurred at Pisa in 1085… Thereafter the system began to spread rapidly…" (Skinner The Foundations of Modern Political Thought).

So, one sees clearly that the issue of whether men could govern themselves has always been a dubious proposition. Or read Aristotle's Politics (found, for example, in McKeon’s The Basic Works of Aristotle) for his discussion on political states, written 3,000 years ago.

Now the purpose of the governance and the settlement is clear – it is a form superior to the individual atomism (it contains many atoms), which functions to satisfy fundamental needs, all of the conservations. We have named the conservations and the source potentials which keep the conservations balanced near equilibrium. Can the atomistic people do it by themselves or must they create a command-control system?

Now clearly such a settlement requires the human division of labor among its action modes. The catchphrase that gets the image right is that in an urban center every task is professionalized. (Loosely speaking, a professional has a definition. It is one who provides a very well-defined service, and can dictate the terms and conditions of his employed action). The most marvelous depiction of a city, of the modal tasks, in a fairly modern city, is the descriptive inventory taken in Mayhew's London Labor and the London Poor.

But clearly urban areas are not self-sufficient. So there must be a well-defined convective input and output from agricultural regions. And since those fluxes depend upon value in trade, there must be a convective flow pattern and balance in trading, input and output.

Can such an area run itself, by collisions, like molecules in a gas or liquid enclosure or within a solid? No. The action modes required would need so many interactive transfers that they cannot be achieved. The first thing that happens is that storage depots – 'markets' – have to precipitate into place. An interior design, suiting economical transport, has to emerge. There is always an appearance of longer distance transport tracks (e.g., people and vehicles walk on or develop trails. These require less energetic effort than paths at random). But then once people precipitate in place, some design efficiency emerges for where and how they segregate their actions - where they live, where they farm, where they defend, where they manufacture, where they service, where they market. The reader can try his hand at such design. It will be creditable. Or he can look at pictures or designs of urban centers through all of history. He will recognize that they too have dealt with similar issues to his, perhaps more creditably, perhaps less. He will also find, that once design selections have been made, successive generations of people track the design and modify it. The process becomes very much like the design of rivers, or the design of all transport nets. Two or more conflicting force systems select the design; conflicts in transport requirements are reconciled by historical development. The natural parts wear in.

Does this make for one fixed design? No. It makes for families, and types, and patterns of designs.

But because of the complex net pattern, some sort of nervous system command-control system must emerge for coordinating. That process might have begun to evolve originally simply from band, group, or tribe leadership, but once urban centers began to interact and diffuse, central urban leadership emerged as the form. But it had to have some strategic rule or rules. It is interesting that the first few known written 'strategic' codes, were the codes of
conduct of cities. These date back about 4,000 years. They preceded the more elaborate codes of Hammurabi (at about 1700 B.C.) and of Moses (of about 1300 B.C.). They indicated clear concern with the relation of rulers and subjects, and subjects to subjects.

As time went on, all possible ideologies were tried - the rule of the one, the few, and the many. By Aristotle’s time (300 B.C.), he could write an extensive review of their relative successes and failures.

What is it that has to be governed? It must be made certain that the fluxes of materials, energy, actions, population, and monies flowed smoothly into the storage bins of the center, that the flows in and out were smooth, that the diffusions were appropriate to survivorship, and that the process would continue into the future. The amount of governing control of the command-control system could be extremely hard wired, governing every action and transaction, or it would be very soft wired, only paying minimal attention to the governing of fluxes. In many modern American cities, because of a particular kind of history, many cities operate with the notion that all that is required by city government is to take care of certain essential maintenance functions, e.g., garbage disposal, fire protection, police protection, water supply. In contrast, a thousand years of European city history is more attuned to the notion of a ruling council representing the interests of the major wealth producing groups in the city.

In any case, cities have to evolve a scheme of rule, a bureaucracy to help rulers carry out the rule, groups who have the competence to assure the many flux balances in primary conservations required for a city to exist. And it must have access to the required potentials. A few interesting introductions to the problems facing the city are the introduction to Max Weber's *The City*, Mumford's *The City in History*, and Jane Jacob’s book on the *Life of American Cities*, and *The Death of American Cities*.

You want to move to a city? (Obviously in modern industrial times you do. In the United States, we have now completed the move of people away from rural and small nearly self-sufficient villages to urban centers in the past two generations. Only five percent of the population is left on the farm. This is one of the most drastic and complete shifts ever made in history.) The rules are relatively simple. You have some relative diffusive freedom to move among cities (within your polity; more restrictively within your ecumene) at the generation level. That diffusive freedom is essentially sufficient to guarantee the distribution that atomisms such as you produce in such a connected region. In any population octave (for example total population for city sizes between 10 million and 5 million, or between 5 million and 2 1/2 million, or on down to sizes between 40,000 and 20,000), the total population in each octave is essentially the same. That means that your selection of city is basically indifferent for all sizes. (Above a starting-up size and a top biggest size city.) You will move among cities, slowly, as you see opportunities ('you' being you, your progeny, their progeny, etc.).

When you get to a city, you will find an elite leadership, and you will find that a considerable chunk of the desirable selections and aspects of the city will be in their hands. And depending on the action skills, or conservational wealth you bring in with you, you can quickly surmise where in the social net you belong. As in the solid state, groups have their ingathered bondings. But really, if you are grown up and socially acclimated (trained in the epigenetic heritage), you know. The only problem you face, if you wish to stay abreast of the flux processes, is how much effort you must make to obtain, retain, or move up or down from your most fitting niche. Different societies have different diffusive impedances to upward and downward motion. The best summary is the catch phrase of current youth "There is no such thing as a free lunch."
Since we are neither writing a "How to" handbook for citizen or ruler, we will not proceed with much more detail. We will make a few comments on the ruler's problem. The ruler does have to oversee the fundamental balances. A more modest view of just overseeing municipal services is possible in some periods; or a Jimmy Walker and many leaders that followed could help run a New York City into the ground. But ultimately the real problems - jobs that produce trade that balance costs that bring in food and materials, that provide investments, that produce people - have to be faced. Again there are periods in which one city could rob from another, or conquer another for tribute. Such is possible. More often, in general, the city has to provide its own support, and perhaps support a distant elite ruler. That requires leadership in getting all of the major power groups in a city to collaborate, set some objectives - whether conscious or not - and work intelligently toward that objective. That literally is a rare if at all existent commodity in American cities. It was the kind of planning that kept a city-state like Florence, or Venice in a forefront for periods of the order of 500-1,000 years. It is time that the process is redeveloped if American cities, and beyond, if the United States as a nation is to survive with health.
Chapter Twelve - How Rivers Work: The Hydrological Network

The running of cities and nations may have overwhelmed or frightened you. So we will step back and give you an introduction to how complex net systems work. A river network on a large land mass may give you the feel. At least you will see how form and function and history all evolve without having to guarantee the birth, life, and death of any particular river in its network.

So, for a first image. Imagine a considerable number of hills of sand, each fairly alike, and above each a faucet with water. Under the law of gravity, we have the basic rule. Water runs downhill. So the water from each faucet plays on the sand and the water runs downhill. But each hill is not exactly like the others, or it develops a history different from the other. One finds each hill developing its pattern of rivers, patterns that change in time. Why? There are two conflicting force systems, both derived from gravity. In one, the water tries to run down hill, in the other, that water carves a passage in the sand, moving sand as a bed load, and thereby determining the course of the river.

A river network is not a flow system of water in a fixed group of channels. It is a live, active system, in which rivers are born, live, and die. Sand linings, that make the river, are moved from region to region. A river is a hydraulic element competent to move its bedload.

But what makes the river? As time goes on, and the hills are worn down, but then uplifted by new potential forces, the river patterns change. But in a statistical sense (statistical mechanical sense), the patterns are stationary. Their density and their general statistical measures will remain fairly constant.

With that very simple introduction, we can approach the hydrological cycle. You may remember that as a result of the meteorological cycle, a parameter emerges, the average rainfall. That represents the faucet flow. Over any area of the earth, the hydrological law states that the rainfall evaporates, runs off, and changes the storage in the ground. The runoff represents the flow of rivers. Over an ocean, there is no river runoff and no ground flow, but there is a net flux out of the ocean region. Here we are not going to deal with rainfalls into oceans, but with rainfall over land areas. And further, we are only going to deal with the near equilibrium situation. Near equilibrium is loosely established in a year. So over that period, the storage in the ground does not change (much). The average or equilibrium hydrological law states that what rains over a region evaporates or runs off.

The difference between the rivers and the runoff on the hills of sand is the speed of the process. With sand, the courses of rivers change in the seconds; in the ground, the courses change in geological time, in millions of years. Yet the runoff is still related to the bedloads that the rivers carry. What we would like to show is that the topography of the land and the nominal downstream course of the rivers on a map (rivers straightened out for their meanders) is basically sufficient to tell one how much runoff the rivers carry, the average position of the water table, and the amount the rivers meander, as an excess over their straight length. Such demonstrations are very much like predicting the change in population in a collection of cities and how that population is distributed. The common problem is how is the physics of conservations, under combined force systems, determined.

Consider two extreme models of the earth - one a rather low shallow blotter; the other a very steep pointy glass pyramid. On the first, all rainfall would evaporate (the runoff would be very small). On the second, all runoff would run off (there would be little time to evaporate). What is a model for the earth? Clearly it is more like the first (consider North America - a lateral extent of about 3,000 miles, spinal mountains about two miles high, porous ground). So, as an
average for the United States - 30 inches per year rainfall, 22 inches per year evaporation, 8 inches per year runoff. Can we estimate the runoff just from topographic maps and river courses?

The first thing one does is sketches in the river valleys. Given the topographic altitude contours and rivers, one can find the ridges of altitude that rivers cannot flow over. A land mass separates into such regions. Inside each region there is a network of rivers starting from some high point and running down to some large body of water, e.g., typically at sea level, or some large evaporative body. Ending on river segments, one can dissect the river valley by a herringbone pattern of areal segments which start from the river valley ridges and run in the best downhill direction. The segments on either side of the river make up the drainage basin for that segment of river. From the slopes of these segments, their downstream length and an average value of the ground permeability, we can figure how much water is added to the river along that river segment. The reason is the follows: Suppose we know the average rainfall is 30 inches. We assume different evaporations (and their different runoffs). If all evaporated there would be no water table near the river. We assume that the water table exists just at the average water height in the river. The river is thus where the water table breaks out of the ground. Thus, by changing the estimate of runoff and solving a ground water flow equation that we derived, we can estimate how much water is running off, and by residue, thus, how much is evaporating. Thus we now know how much water has been added to that segment of the river. If we can carry that program out, segment by river segment, we can compute how much runoff there is in that river valley.

At the same time, the program has given us the location of the water table for any region in the river valley. Assuming that the water table breaks out of the river. (The scheme makes moderate errors for large ground faults and in exceptional regions of major waterfalls.) Now turn to the river.

From the flow and the altitude contours, we can tell the slope of the water surface. That slope relates to the law of flow. But the nominal path of the river has a much greater slope. How can that be? The river must meander; it must increase its arc length so that it does not flow so fast. Why not? Because actually it is the bed load and the means by which the river can scour the bed and banks of the river which determines both the river shape and its side-to-side erosions. Thus we can compute the meanders, not their exact directions or locations. This illustrates the lifelike character of rivers under their governing force systems.

It is possible to go further, and say something about the cross-sectional shape of the river and the local character of the river bed plain that is carved out. Rivers carve. Thus their velocity cannot range too widely. They lose competence to carve below one foot per second, and they carve quickly at ten feet per second. Thus, even when rivers have very large variations in their seasonal flows (such as a million to one), their velocities do not change much. Thus it is not their height which changes so greatly as it is their lateral extent in the river plain. It becomes shaped to permit that variation (e.g., by shortening meanders)

One more piece of the basic physics of explanation. If one examines flow in a channel, one usually considers that the shear viscosity of the wall is the governing factor in a flow field. Thus one would expect the viscosity of water to govern. This is not the case in a river. That shearing force of water puts the bed load into movement, and it is that working bed load which determines the effective viscosity of the boundary layer. That layer is the scouring layer for the entire process, as well as the determinant of the flow.

The whole process is just like in the sand pile, but with the erosion process slowed down.

So finally, what makes the river courses? Yesteryear's rains. Yesteryear's rains make the current rivers, and the current rivers make today's flows.
Moral for Man. If you haven't geological time, to wait for new earth uplifts, consider returning some of the soil that washes down to sea. In any case, learn to harvest and cultivate your water resources very carefully.

Moral for the reader. With the very few potentials and conservations note that a very complex viable system runs itself. The chain of unlocking the causalities was very strange, much different from the usual more casual (as causal) engineering view. Perhaps this view may help the reader when he reflects again on managing the flow and distribution of humanity among cities and the agricultural resources of the land.

In geological times, the land can forego river systems and let them dry up in some regions, until volcanism or climatic change may reactivate them. The same can be true for living systems. Does industrial man have that long term luxury that other species may have?
Chapter Thirteen - On Organizing or Running of Organizations

Or how to succeed or fail in running organizations by really trying. The start-up problem is really quite different from the running problem in which the only one who may be starting up is you.

If you want to learn something about the requirements of the craft of power, we can suggest Siu's *On The Craft of Power*. You may not like its themes, but if you don't, then the craft of power is not for you.

So now turn toward starting up an organization. What images do we have in mind? Starting up a business, starting up a social organization, starting up a union, a political movement.

Start up requires an unstable field, a situation in which one or more unstable fluctuations emerge out of the non-equilibrium unrest of the field and one sufficient to trigger and converge on the organization of new form.

So whatever you are, a person trying to start up an organization, or the beginning fluctuation of a new hurricane, the first aspect of the problem is that you are compelled to the action. Organizational start ups are not casual. You really have to decide whether you have the 'unlimited' energetics to be a successful fluctuation, and whether the field out there is ready for such as you to try the task of organization. You may not be the first, or you may not know of others who have tried, all of which increase the difficulty, or by the time you try, you may know of others who have tried and you use some of their experience to build on. Start up in all systems is like that, even those that do not cogitate about the process. The fluctuating compulsion which creates your impulse is like that, but your compulsion is not unique (only your impulse).

What are you organizing for? Believe it or not, you are organizing for the first day. You are organizing an engine process, that will turn over, day by day, and do what it is supposed to, but first you have to get the first day started, and get it organized so that the results of the first day begets the second day, etc. Blessed etc. When you have done both, the first day, and you have the etc. rule, you have succeeded in starting up an organization. What are you doing? You are the general purpose engine who is assembling all the materials, parts, who simulates any missing piece, and who is trying to get the schedule of a factory process and a factory day into place. After that you are the escapement for the engine, putting in the nonlinear pulses that keep the thing moving from day to day. All that is part of the general prescription. Let's look at it in a little closer detail.

You need to find a substrate, a piece of that unstable field, wherein your organization can lodge (your basement, a space you rent, or borrow illustrates the poor man's ways). You need to bring together active pieces before they squirm away. You have to nurture all of the pieces, and you have to provide initial stores to get things started. You have to have enough stores to cover foreseeable fluctuations. A very delightful example of a company start-up (a large company) from its first day is Marquis James' *Biography of a Business 1792-1942*. You must begin the process of developing all the necessary binding forces and configurations.

It is not difficult to find a few people (for an affair, for a partner, for followers, for employees, investors, believers). People are gullible. They want to believe. They want to be led. If the field is unstable, it is easy to find them. But they have to be something like you need, e.g., good workers, matched to the task. Experience shows that you can run almost as efficient an organization with poor people, poor materials, poor equipment, etc., but the difference in wear and tear on the organizing elite or command-control system is tremendous.
It is an important requirement to program the spectrum of necessary activities, a check list through all the required conservations, and scaled at a number of the basic time scales required for survival.

We are not writing a management manual, an advice to the lovelorn, how to succeed in business without trying handbook, or any of the other elaborate sociological derivative documents. We will not insist upon a style. There are the leader figures who are masterful, crafty, autocratic, friendly, aloof, etc. But the important thing is a sense of timing, a sense of the relevant, and sustained push. The very specialized details of any field are quickly picked up. Deeply? No. Not unless you spend a great deal of time and effort on the task, and that is not necessarily the important property of a leader.

Mostly you need the energetic self-push. And the field process ready for you, or such as you.
Chapter Fourteen - On Bureaucracies

All complex systems have them. In human societies this subject is supposed to be the province of sociology and there is a great deal of literature on the subject (for example, one might start such explorations from Aristotle, Durkheim, Max Weber. One must always marvel on how much of organized western thinking is to be found first in Aristotle). But most often, that literature seems to be extremely wordy, at best typological. The basic principles within organization do not come into focus. So the question we address is much more the basic physical principles behind organization.

In physics, the basic concept of bureaucracy is to be related to the mechanisms or parts of machines (or active engines - active always refers to energy exchanging, an engine is a prime mover which converts stores of potential energy into the energy of motion with the 'potential' capability of doing work against internal losses. In order to be an engine, you do not have to be doing work all the time, you may be running in an idling mode, just doing enough internal work to overcome the internal dissipations that are a concomitant of your having mechanical parts, or mechanisms. We provide all these engineering definitions to indicate that the entire subject relates to the 'machinery' of systems, and such machinery has thermodynamic connections. A complex organism is organized homeokinetically by internal engine processes. Even the command-control system, the prince, or the elites in societies are internal engines.

An engine takes a working substance through a process cycle and has the capability of doing work. Examples?

Gasoline is taken in an internal combustion engine, put through a motional and transformation cycle, burnt, and replaced to keep the engine working. (To be strict about it, we have to include the process of recombining the combustion products and returning them to the original state of gasoline. Notice that in our current energy crisis it is this sort of issue of renewal that faces us. In all such renewed processes, there must be a source of potential to pay the charges. That is a basic reason, having at least in part exhausted earth resources, we turn toward a much less limited solar source of energy. An engine is also said to take energy from one potential and reject it to a lower potential. In that view we do not have to pay detailed attention to the working substance and its return. The two views are not basically different.)

The same story is true for the external combustion steam engine, in which - say - coal or oil or gas is burned as fuel to produce steam.

The same story is true for the cell, or the human organism, or the human society, or the star. Fuel is found, burned, work is extracted by moving parts suitably arranged.

So we have stressed the engine process. We have not told how the process is used to discharge all the functions of the organism, system, or atomism. These become the action modes, and the spectral processes associated with action modes. But about these the engine itself 'cares' not a whit. It had generally been reasonably designed for the functions.

But now we turn to the bureaucracy. In general, they 'care' even less about the function of the organism. They are related largely only to the operation of the machines; they are the subordinate parts, commonly viewed as the 'cogs.' (Being humans, they can act as rather general purpose cogs.)

What is of some interest is that physics a long time ago classified elementary mechanisms -machines as they were called. They had the pulley, and the lever, and the screw, etc. This was sort of a rudimentary classification of motion transformers.

In a contribution to engineering, physical notions have offered a richer set of ideas. There are two physical classes of 'linkages,' those that depend on solid elements and 'hard geared'
transfer motions; those that depend on fluids, 'soft-gearred' or 'no gearede' coupling, and transfer rate of motion. Mechanical engineering, for example, deals elaborately with many classes of hard mechanical linkages.

But as a broader kind of classification we have the notion of transformation, transduction, and transpondance as more general engineering notions. A transducer transforms one physical quantity into another. A mile of gasoline runs through an engine transducer produces 16 miles of motion on the flat. A dollar through the market engine produces a pound of grapes. An hours worth of electric current plates out a definite amount of metal in an electrochemical bath.

A transformer changes one magnitude of a physical quantity into another magnitude of the same quantity. An electric transformer changes 220 volts AC to 110 volts AC. A pulley changes one inch of motion to five inches of motion. A transponder transforms any received signal into its own output signal. An alarm (or a message) may be triggered by any number of signal inputs - sound, light, heat, wind. Or, a young person may say, 'Regardless of what I say, or do, I get the same reasons from my father!'

How are such elements to be used? Well, in a factory (or an engine), these are arranged as station transfer apparatuses. They make up the linkages, and transformations, and transport, and lubrication mechanisms. They make the factory and its many engine processes work by contributing the working parts.

Now in most successful engine design, the systems are designed amply but with a tight line. There is a minimum of redundancy. There are neither too many or too few parts. The problem becomes more exacerbated when the 'engine' systems that are designed involve soft couplings (as a primitive example, fluid couplings). Consider the problem as it faces a leader. He would like to get a bureaucracy around him that is sufficient for the purpose. Often when the organization is poor, but running efficiently, he commonly succeeds in having such a minimum chain of series and parallel command through that group around him. But as the organization gets bigger and richer, it begins to build up too many layers and the useful flow of authority down and information flow up is impeded, shut off. All of the satiric truths of Parkinson begin to show up. As the organization gets bigger and richer, it begins to build up too many layers and the useful flow of authority down and information flow up is impeded, shut off. All of the satiric truths of Parkinson begin to show up. A most common result in large organizations is that middle management levels prevent any useful flow of information going back up and intended authority coming down. Many people think that this is characteristic only of what they call 'government bureaucracy' (which government such an accusation is thrown at, doesn't matter), but it is true of most such organization. When particularly useless or disturbing centers emerge in these chain of commands, leadership seldom cuts the faulty part out. They simply encase the fault, wrap it in a cocoon, isolate it and hope it will get absorbed. Instead it generally festeres and puts out poison. The system tends to get hardened in the arterial communications.

In a certain sense this is the typical life characteristics of living systems. But there are obvious things that can be done to keep the system alive longer. One cannot count on these measures equally at all stages of life.

Exercise all channels. Do not let poor channels fester. Keep the lines slim with good response times, and with not too much redundancy. Keep atomisms (people, equipment) moving up and out through the system. Turn over at a well chosen rate. Spawn new organization at a best suited rate. Let the bureaucracy have a significant interest in the success of the organization.

The basic definition of a good sociological science would have been the science of the organization of the total work process of a social organization, had it emerged from the 18th Century Enlightenment into the 19th Century with an understanding of the physics which we now call homeokinetic physics, a physics of complex systems. (See Bottomore and Nisbet A
History of Sociological Analysis.) Instead, it is clear that they emerged into the 19th Century only with the Newtonian world-machine image of a gravitational force, inadequate for noisy earth-bound, life-bound processes. And so instead sociological scientists elected the idea of progress, more perfect systems. By the time of the end of the 19th Century (say Marx-Engels to Durkheim to Weber then on to the social engineer experts of the work process) any possible connection with a physics of complex systems had long been disconnected.

But in any case, all systems precipitate bureaucracies, and institutions, and they layer them. But there simply hasn't been enough time to develop the diversity of organization and experience that life and the evolution of its genetic code has had. The social leader, most often only gets a smattering of epigenetic training for the purpose (at most a few generations of legacy), whereas the bureaucracy has a much greater continuity in transfer.

We will pursue a rudimentary example, one that most of us undergo, the problem of organizing a family structure today (or yesterday). We assume that you are now a parent leader adult (or at least ah observer on some) and once you were a child follower in such a small system. We will ask a kind of single question. How do you keep the young in line as the bottom 'bureaucracy' in this social institution? The loose answer is that you almost cannot unless the rest of the society cooperates. When a child goes into rebellion, becomes a kinetically hot particle, there is almost no way you can handle it. Oh yes if you have unlimited resources, it is possible to build up a whole hierarchy which isolates you from the problem, but that doesn't solve the problem, only your problem.

Solutions depend, in the large, on there being a uniform perception throughout the entire social field. If, wherever the child interacts, in the institutions of the play group, the child's peers, in the school, in the information media, in the religious institutions, in other information, in family structures, the same regulation and control message appears, then the control is possible in such soft coupled systems. But, as today, when the field is in process of changing, when the messages received are highly disparate, you can only hope for luck and very particular circumstance. This is not a plea for traditional society but an objective sense of what it takes to hold together useful bureaucracies that (a) do not clog up the avenues by inaction, and (b) are not in such turmoil that once again coupled action is not possible. The relationships between top and bottom layers of a system have to be fairly right, in bounds, if the system is to work.
Chapter Fifteen - On Running a National Polity

We address the problem of the elites who manage to capture the power running the central command-control of a large 'political' organization. Note that this is not the start-up issue. It is the take over issue, how to run a system which they have taken over. The basic problem they have to face is to reconcile many interests, both central and remotely local. They obviously have some considerable experience with power. If they don't, they either have to acquire it quickly, or find some advisors who cannot share for power, for special reasons. It is highly customary to destroy or otherwise render impotent all those in the vicinity who may pose a threat to take over of such central power.

Why does the populace permit or tolerate such processes? Because that central elite has generally the command of power (e.g., enforcing machinery such as military power) which can be exercised for real or as threat, against localized group's power. The possible application of power of the entire populace might itself be great enough, but as an available fluctuation, it is not available quickly enough. (For example, in democratic elections, suppose the populace has elected a central authority about which they feel uneasy. The machinery to redo an election is so cumbersome and time delayed that they will not do it. So the unpopular elite have a fairly definite period to try to consolidate power, before he can be opposed or disposed.)

Consider the following elementary argument advanced by some segments of a 'powerful' nation each time some external crises appears. "Why don't we just march in and take over?" The following calculation must be made. One can march in and take over. True. But what is the chance of failure? Suppose one marches in a second time. What then is the chance of failing either time? etc. Further, what is the damage that such marching in will do?

Thus clearly the elite, who have taken over power, and who know what it costs to take over power, and who know how much power they wield, do not enter in as impulsively into such adventures. Actually the very command-control apparatus of the human brain, that which in fact endows elites with their characteristics, generally leads to wars. One makes the prior physical estimate that peaceful trade relations will be broken up on the average of once a generation within the ecumene, and - once strong polities are established - at least once a generation large disputes between central activity and local authorities will take place. These estimates fit with the experimental facts.

Historians most often do spend time seeking out the very specific explanations (or at least descriptions) and the whole chain of events that particular elite were involved in for particular periods. That is as it should be. But there must be some understanding that there are forces acting and patternning developing more general than the detailed gyration of a particular colliding atomism. That is what we bring to these subjects, a common physical base for all such processes. It would be foolish of the historian to deny that elites make decisions about the processes around them on the basis of their command-control systems. If there is the notion that each brain is unique in behavior, or that so much complexity lies in the brain that its branching selections defy understanding, this misunderstands physical mechanism. The task of life is met by a handful of conservations, but a few handful of modes. Anger, greed, etc., make up these modes.

Thus, one may seek some common interpretation from the common experimental findings, and from the common humanity which one shares with elites, as well as the physical processes.

Elites act to satisfy their own ego interests. This would be the catchphrase in freedom of will terms. Dressed up physically, the selection of strategies by hyperactive people who are
involved in organizing and binding social processes among groups of people, is one that fits their own action mode chain or cycle, i.e., their own 'needs.'

The anxiety, terror, discomfort, hurt, pain, in fact deprivation of life that these large scale waves of national motion, known as wars or conflicts, inflict on groups of people seldom deters elites. Or better put, effective resistance to initiation of such adventure exists, but once a generation the impulse can be put over. Then the populace again remembers prudence.

A marvelous analysis of this process was begun by L. Richardson. The curious may like to explore his writings.

Fine. So now we could begin to talk about the wise ruler and the bad ruler, not because we are addressing the morality, but just to stress the range of performance that is possible. Any particular ruler (a) seldom concerns himself with moral issues (although he will generally believe in his personal morality), and (b) seldom winds up pure one or the other. We are talking about 'good' impulses and 'bad' impulses that drive a system. So addressed, the metaphor is slightly ridiculous.

What we write is not an issue of the 'ought to be' and the 'is' of society. Rather, in the sense of thermodynamics, we provide an ideal engine model which indicates the greatest possible efficiency that can be achieved (efficiency is how much energy is extracted from source potentials and rejected to sink potentials as compared to the amount of useful work that the engine can do. For flow processes, wherein the purpose of the work is simply to keep the engine running - in thermodynamics this would be viewed as degenerate engine performance - work is dissipated into internal processes. Thus ideal efficiency in those systems are to be related to the internally dissipative power in minimally essential flow streams.). We indicate the minimum tolerable performance that can keep the engine running without breakdown. Some will still insist on interpreting that as the 'ought' and 'is' of society.

The 'good' ruler (we will now change this to 'ideal' ruler, meaning the ruler who achieves ideal performance) can only succeed in one overall goal - that the performance of the system has not been unnecessarily degraded, and in fact improved over the 'generation' of his rule. All systems will be subjected to the vicissitudinal fluctuations of the environment and its potentials (flood, storm, earthquake, drought, pestilence, as well as the other polity-made fluctuations. After all note that other rulers likely came into power by some impulsive fluctuation). Thus, like all thermodynamic systems, the ruler is faced by the fluctuating forces that arise from all possible directions (even from inside him), and at a great variety of time scales. Chaos? No. We are back to the central issue we stated right from the beginning. The brain develops an ordered perception of what is out there, and that permits an orderly space-time-energy sequence of action. After all, as we have described the basic action of the individual organism. It senses to perceive to motor act so that it can sense to perceive to motor act (and it eats to power the motor act, and intermittently it reproduces). So the ruler too, develops a rhythm of action to deal with the fluctuations.

While atomistic fluctuations among people can go down to the tenth second, and are organized at the six second level, with behavioral action complexes appearing at the one hour level, many being completed in perhaps four hours (work episodes. digestion episodes), the atomistic day of the ruler appears at the night-day level. For the daily processes, he needs no high level cognitive processes. For those he assigns routine bureaucrats - e.g.. policemen, postmen, etc. All of this may be referred to as the routine policing function. In the oldest written rule codes known, we find evidence for such functions being codified. No one writes a total detailed handbook of all of such requirements, because the internal body apparatus takes care of
most of them. The point to be made is that the ideal ruler understands the relation between
physiology, and behavior, and the policeman encoding encompasses that understanding (think
about all the foolish 'dos' and 'don'ts' which elites have tried to promulgate at various times in
history, including yesterday's history).

The bad ruler, on the other hand, can so impede communal motion and relations by
encouraging or developing over elaborate bureaucracy. That precipitates 'middle management'
crises at this most primitive level and stultifies social reactivity.

There are good physiological-social reasons for the social week (e.g., work week),
monthly and seasonal fluctuations. We need not detail them. But the ideal ruler senses the
rhythms of these processes and incorporates them into the operation of the society. The
sprinklings of all sorts of seasonal holidays through all cultures attests to their ubiquity. But we
come to the year, at which the cycle of the seasons closes. Every ruler knows that this must be a
basic planning epoch. The first near full balance takes place. Oh yes, if we haven't mentioned it
before, we ought to now. What does a ruler do? He oversees the flows and balances. What
flows and balances? The same conservations we have been alluding to all along. He must see
that materials, energies, action modes, population number, and value-in-trade come out to near
equilibrium amounts. How often? For the generation of his power, for each year, nearly for
each day.

So here at the end of the year, he knows his first approximate balance (obviously he has
been attending to the intermediate periods, e.g., seasonal). The food crop is in. Plans for the
next food crop can be made. The energy balances have been made. Manpower needs for all
purposes can be assessed. Trade balances can be assessed.

It is interesting to note, in passing, that all of these processes had been clearly marked out
by the time of the first city-state empires in ancient Sumeria, by the Egyptians, and so on, up
through the Romans. Yet in the decline of the Roman empire and the dry up (or stasis) of the
European urban trade when it was cut by Islam, there was a considerable period in which the first
new rulers, e.g., Charlemagne, did not quite have a full sense of how to run these issues, e.g., of
graded taxation for purposes of central government, and it took a few generations to relearn such
arts (see Barraclough The Crucible of Europe).

So much of the ruler's decision making processes have to do with the yearly time scale.
For that he has to develop a bureaucracy that keeps him in touch with all of the centralized
affairs of his entire polity, the local affairs, and the outside affairs. These are his three basic
images - the whole organism, the local parts, and the outside.

Obviously, the temptation is very great to immediately use biological analogues and
metaphors. This has been a practice throughout history. Why? Because the body and its parts
always stand before our eyes as a prime example of a complex working system. We think that
there is no reason not to look into the body for comparative information as to how the body
solves a problem. But - we have asked that you seek, ergodically, a broader horizon. The
problem is not that the body does it and all systems do it like the body. It is that all systems do it
(balance their conservations, involving a 'knowledge' of self parts, and outside in the internal
fields). Thus it is the case that all systems do it, and thus the body does it like all other systems.
As a catch phrase, we offer the following principle.

One may anthropomorphize nature, and objectivize self (or the opposite); both views are
valid, because they are aspects of only one reality, that of physical processes.

But we cannot adopt the detailed morphology of one system for another. Each tends to
have its own scale, and scaling laws (of space, time, given the materials and forces). So the
ruler's problem, in designing a bureaucracy for the annual decision making processes, is to fit his own human circumstances rather than any other system's organic structure. It does best when it is built on an understanding of the nature of physiology, of social bonding, of geography - climate - ecology, and the existing epigenetic and technological rate potentials.

A simple illustration. There is some reasonable evidence that early rulers understood the need to establish food storage bins. In good years, and in harvest, the populace brought the earth's fruits to the ruler, who stored it, and also distributed it in bad times. At least, some historians believe this to be one of the earliest bases for establishing the power of elite rulers. In that view, the grasp of rule by force was a later (or contemporary) process.

If we were dealing with hard geared coupled processes, it would be obvious that the selection of machine linkages to drive a system has to be compatible with the cycles of all of the intermediate systems. But it is almost as obvious, that even if soft geared or fluid coupled field processes exist, while they may permit more slippages, they behave well if you don't create unnecessary turbulent waves, eddies, and frictions. A regular coupling of all of the cyclic processes keeps the system moving most ideally. So don't make unnecessary waves, in efficient systems. On the other hand, a bureaucracy becomes enamored of the regulation of its cyclic process (that is its rule, to furnish linkages). When that becomes too rigid to permit the very kind of operation which the loose coupling requires, accommodative operation, then all that the system develops is 'noise,' from the squeaky mismatches that the bureaucrats develop. All this the ideal ruler learns (or knows). Efficient systems do not run with no noise or slippage; they run with sufficient losses to accommodate to all of the fluctuating vicissitudes.

So the ruler may design the bureaucracy that he sees fitting for the operational yearly scale. Another note required is that the ruler must have some sense of the integrative periods for sensing - perception - motor action. At a human organismic level, this is the order of 0.3 of a second. (Three basic serial nervous processes are involved.) For the important social time scale of the day, the ruler must know that there is a near equilibrium scale to those of atomistic fluctuations, of about three days. It is easily seen in the fluctuations of decision making in the stock market, an open market where many people are free to exhibit their fluctuating decision making. Loosely speaking, we would suggest that the time scale emerges from the lag (memory) properties of the human brain. A 'strategy' is adapted for the day (largely driven only by the routine action modes and vicissitudes of the day). At most there is a loose comparative review of strategy the next day. Generally the decision (unless the previous day was a disaster) is to repeat yesterday's performance. Thus coherence in decision making is held for up to about three days before a switch in strategy. One notes that the fluctuating drive is not 'strong,' so as to make big waves. But it is definite. It is like saccadic movements of the eye, or the fiddling with the wheel that a driver does, or the compulsion to push an elevator button that obviously has been pushed. It is part of the microjitter of the intercourse of life as it is addressed by the human brain.

In a related much longer process, one finds the same bandwidth for the yearly process. Because of the yearly fluctuation in the earth's geographic - climatic - ecological processes, Man in society has to hold and modify strategic views. So a three-year microprocess emerges in social intercourse. One finds it in business fluctuations, in the demand and transports of various goods and services.

But that miniforce, fluctuations in outlook toward running and balancing the conservations and dealing with the potentials, is what creates the political time scale. It descends down to us in the form of our 2-4-6 year election process. In Italian cities, it revealed itself in the yearly election of a government, and the much too shortness of the period. It is contained in the
selection of citizen governors in ancient Greek cities. It is not far removed from the average fluctuation (or high frequency fluctuation) of king rulers. Whether a ruler's power is very great, or his position hereditary, or his life very long, the more common case is a relatively short fluctuating rule, in which some rulers manage to hang on for quite a few more fluctuations. That upper limit tends to be the generation. Thus one may assert that rulers tend to hang on for one to ten political fluctuations. The lower limit matches the political perception of people; the upper limit the epoch in a human life in which people can perceive a ruler to be powerful enough, personally, to rule.

But the very uncertainty of that extensive range makes it necessary for rulers to plan ahead for many more than one political fluctuation. As politicians are reputed to say: "The purpose of office is to get elected the next time," or life is the process of getting through today so that you can face tomorrow.

We are saying that the ideal ruler knows this and thus knows that an important but much more personal activity he must perform, is to plan for many more than one yearly or short political term in office. In fact he must plan for a generation. For that he may not require any extensive bureaucracy, perhaps only an advisor or two (himself, a friend, spouse?). Do many rulers do so? No. It distinguishes politicians from statesmen.

So if the ruler is skilled, he manages for a generation. What does he do? Well, as we indicated, first he takes care of himself. For whatever reasons, he can get and depends on the output of many people for his support. (The average elite of medium and large organizations depend on perhaps 25 people for their support.) Then he is involved with his local support bureaucracy (this is perhaps 100 people in number. The limitations are in fact physiological. One has difficulty in doing more than recognizing 500 faces with any social utility. A group of 100 involves some useful interaction). He does what he believes necessary to oversee the conservative balances. He deals with problems inside and outside. At times he faces the problem: trade or war? Can he achieve national polity objectives by interactive negotiations, or is it timely to use force? That thought is horrible to most thinking peasantry much of the time (it is to us), but this gainsays says not one bit that we all have been willing to fight, and that we are much more willing to fight when young, adolescent, and male. So a priori, we sense that rulers will find it convenient, useful, or necessary to enter into war, and involve - largely - the young in the process. (As one gets older, it is easier to involve the young in such processes.) As long as people remember the horrors (and if there is no persistent provocation), of them oppose the theme. Until the hurt is forgotten, then new generations can face war again.

You can protest - during your generation. The next generation forgets your protest. They have to be provoked until they too protest. So there is no social way to break the chain. Biological redesign? Perhaps, ultimately, but that is not what we are writing about now.

But clearly what happens in a polity depends on how it came together in the past, its people, and the kind of ruler elites that the people permit to well up to the top (whether by their choice or inaction). Then the ruler may lead, but it depends on the people following. So a circular process of social fluctuations emerge. Some make bigger waves than others.
Chapter Sixteen - An Operation in an Ecumene

As a perspective, since we have moved up to the scale of civilizations, the scale in which many polities exist, each with their own barriers to free diffusion, each with their own internal codification of internal action and behavior, but engaged in convectively interactive trade, we want to present some notion of the overall process that goes on. First we will present the picture of an isolated culture. The latent process which makes civilization can be seen in that small molecularity, with somewhat shortened up time scales.

First there is some founder theme which led to the culture ingathering and starting up. Then there is an enculturation period. For small cultures, this may be of the order of 5-10 generations (200 years as a round measure). That enculturation period becomes an archaic view for a subsequent enculturation period. There then may be a few such enculturation periods before the culture disappears. Thus perhaps 300-400 years is the average life of a small culture. The 'present' is about three generations (70 years) up to the existing real earth time. It lives in the epigenetic heritage of the people as 'now.' It is the time - person scale of grandparent - parent - children. The 'future' is one day, one year at most, further out.

Turn now to the ecumene, in which many regional cultures coalesced, formed settlements, and polities, were overrun, overran, dispersed enslaved, ennobled. In one or more regions of the trading ecumene there are cultural homeogeneities. With convective trade and diffusion across the various barriers of cultural borders, political borders, diffusive energetics of transforming among conservations (cross-coupling transport coefficients), the borders between labor-divisive groups, the need for common symbolic languages arose and were satisfied. Language is the catalytic signal which promotes an evocation of an action mode, or switching among action modes. In the complex system's behavior, language always emerges as a characteristic modal process, near the command-control apparatus, to control switching among modes. It uses whatever suitable materials are at hand, with small energetics.

In the hominid, and Homo (such as erectus), the use of tools became a more formal linguistic element between self and outside. The 'tool' duplicated ones motor apparatus; in time ones sensory, and in fact structural apparatuses. In modern man, it certainly became spoken and symbolic language (it may have been so earlier, but we doubt it).

In modern urban society, it became a full inscribed symbolic construct. Witness this in the astronomical time keeping structures, in the magico-religious symbols, in the religious structures starting with the urban centers in Sumer, on to the Egyptian (and Meso-American, and African). And in time, for the busy daily transactions of trade, it finally became written language in such centers. Always using materials at hand for the symbolism, and used at low energetic cost, as amplifiers - to evoke, to provoke.

What is held in the ecumene, in all such records, mental, oral, or written? An extended epigenetic heritage of the order of 500 years. It is a heritage longer than the earlier form of isolate culture, which could be coherently passed for perhaps ten generations until it became a mythic etc. Founding legends may almost disappear or become the Ur-culture, the panoply of spirits, gods, or God, who was originally responsible. But societies hold their mythic view in simple capsulated form.

Examples? Old history, our religious beliefs, our western picture of norms of conduct and civilization are formed out of the period roughly 800 to 1500 (Charlemagne - as the 'Holy' reformation of an earlier Roman Empire, to the age of modern discovery). But the way we think of that history is archaic.
Jump to the oldest documented form we can trust for chronology – the historian Herodotus. What mythic history does he present, writing in Greece at 500 B.C. It is the story of the heroes of the earlier Mycenaean Age. Add up his chronology and it leads quite perfectly to the fall of Troy. It does not depend on the Homeric legendary transmission (or not solely) of 800 B.C. Clearly there were many historical paths to that earlier period of 1300 B.C. which was the mythic period for Greece 500 B.C. You may chase up your own examples.

The subsequent, more immediate 500 years furnishes the enculturation period for the civilization. Our western view is loaded with the story, after the Age of Exploration, of the development of the political nation - states of Europe (Americans with their side of it. Near Eastern Asians have their side of it, the aftermath of the Islamic - now mythic - period, and the Byzantine story. How many know the African story, or the Chinese story, or the really central story of the rule of the central Asian steppes - a basic and dominant power over eastern and western civilization from the period of 800 B.C. to almost 1600 A.D.? Only now does a more universal single ecumene really develop.)

The 'present' is that period, three generations to now, which presents us with our modern epigenetic and technological heritage. In fact 'half' of us are tied completely to that period by the strings of immediate memory. The other half hears about it incessantly.

And the future? The next three days (the direct wave propagative time scale); the month, the year, and quickly fading, the next decade or generation. Yet most of us, through family, tie ourselves to the next generation. It is just that we do not organize it very coherently. Some people do, which is what ties us to that future. In fact, it is our premise that the three prior time scales - 1000-500 years ago (mythic), 500-present (enculturating), 70 years ago to now (the ecumene's present) as a mixing pot of atomistic process, permits us prediction out for three more generations (70 years). After that the social process becomes incoherent.

Why 70 years and why can it be coherent? Note that this is longer than the individual, and really depends very little on anyone particular elite ruler. It may of course represent a motion in history of a large number of elite rulers, those who give the particular past years its particular fluctuating color. In this context, we believe we may have resolved the great perplexing question of what is a theory of history? Is it the history of the great man, is it the history of the people? What we are saying is that an equilibrium (or near equilibrium) of living processes is reached in any three generations. This no longer depends on the individual's fluctuations. But, if modern man, interacting in urban societies, with convective trade, with rapid and large vocabulary languages (many switch states) and written long, livid language, throws up a second isotopic species, highly active elites, they constitute a second separate distribution in the populace. As a result of their activity, they color up the emergent social history, by their selection process. They do not have to be adored, one by one. As a group, one can estimate their number in any era, and where they (one generation) may come from, and where they (a subsequent generation) may go. This is a historical determinism, but a physical determinism, different from any that has been written heretofore.

So we may sense the problem in any small slice of the civilizational epoch. If you know your mythic history, if you know your enculturation history, if you know the recent morphology - of city-states, nations, political organisms, cultures, the flow of conservations for the past three generations, the epigenetic and technological state, you can estimate what the next generation of elites are going to be, what kind of decision making process will go on, what kinds of new balances in materials, energies, actions, population, and selections of future technologies will go on. You can estimate the fluxes, the amounts of war like dissonances that will take place. Is that
knowledge good or bad for you? If we were religious, we would say, "Let God help you!" Since we are not, we will simply say "Let nature take its course!" We could say "May your nature, and those you associate with help you!", for as an individual you are nearly helpless. In 'good' times, you can be cheerful about it. Who among us can be cheerful today? Not until enough social coherence develops to take us over our current crises. And then? Well perhaps, or perhaps not, a brighter future might be found after 2050. That will depend on what a great number of us do to make 'ideal' rulers well up. But that die is unfortunately already cast.
Chapter Seventeen - On Operating a Company

Do you really want to operate a company, your own company? Remember, for this you have to be, somewhat, a breed apart (not a species, just a breed). You have to be willing to work hard (the usual statement is that medium sized executives work 12 hours a day; large sized 16 hours. Sex? Chalk it off, except for quick rolls in the hay. Family, ditto. Recreation, ditto. You may get to eat more, or better, but you will find life becomes quite compulsive. Aren't there any relaxed types? Certainly, but very few. You have to drive). You don't always get paid well. If you succeed, you do, but the success rate is very small. Only a few percent become such elites - that is people who run and receive support from a large number of people. Most of the others, e.g., small businesses, turn over as frequently as one-third their number per year. A ten year life expectancy is long.) You have to fill many tasks. The basic thing in a company is to schedule (manage) the following eight bureaucratic functions and departments very well (for a manufacturing company – similar modes are identifiable for other kinds of companies)

1. Sales
2. Fiscal management
3. Procurement
4. Production
5. Engineering
6. Research and development
7. Quality control
8. Maintenance
9. Advertising

We cannot tell you how many companies disregard the purity of attention that these basic functions require. The point to all of these functions that they provide you, as a company organism, with a present and a future among the essential conservations and flows.

When you start you may have to perform all these functions single-handedly, and delegate them slowly, as the economic turnover permits. But you must always schedule watchdog escapements to make certain that each of these engine processes are turning over. The time scales? The day, the week, the month, the season, the year, five years, ten years, a generation. Do most managements do this? No. Does doing it guarantee success? No. But doing it in an uncluttered bureaucratic way, and paying careful attention to your functioning in the social field gives you a better chance to find a niche, grow, and survive.

For more details, go to management manuals. Many (for example, Harvard Business School) will tell you. Take chances before you have made it. Become more conservative after you have. We detect a different philosophy in such companies as DuPont (bet your bankroll on nylon), and General Electric (spawns new risk companies, which may either make it and spawn, or die). So don't hang on one strategy, just work hard, be bright, aggressive, charming, and pay attention!

In any case, remember that poor management (in too many compartments) wrecks businesses.
Chapter Eighteen - On the Planet Earth

The earth is a near spherical body, largely solidified, one of nearly a dozen such bodies which revolve in nearly circular orbits around the sun in a fairly common plane of revolution. Many of these major planetary bodies have smaller satellites, moons that revolve around them. The system of such bodies is known as the solar system. The near circular orbits of the major planets are more closely elliptical, with the sun at one of the two 'centers' (or foci) of their ellipses. The basic physical explanation of these motions and orbits, in terms of a universal force of gravitational attraction was developed by Newton 300 years ago, launching the new era and confidence of the modern science of physics. From that point on, physics had to take the path of being quantitative, predictive, explanatory as to temporal processes, but no longer occupied with ultimate philosophic explanations. Instead it required always touching base with the experimental reality out there. Self-consistency, parsimony - of both principles and materials, far reaching, universal at all scales became the task. But it also led to such knowledge being layered, having to deal with many orderings of information of the reality of time, but always by the same compact ideas.

After an initial heyday, in the 17th and 18th Centuries, in which the Newtonian construct of mechanics made extensive strides, in fact helped lead the 18th Century Enlightenment, the Age in which it was believed that rational thought based on such science could explain everything, that belief foundered when it struck the intractable noisiness of the history and evolution of biological organisms and social processes. Physics than withdrew from the general arena, of trying to explain everything, to its special 'pure' provenance. But, as we claim, that initial failure was no wonder. All of the other forces of physics hadn’t been discovered and described yet (we have seen and will see how important the electrodynamic forces is - in all chemical bonding, gravity is largely the organizing force at large size); all of the better methods (such as statistical mechanics, thermodynamics, relativistic mechanics, quantum mechanics) had not yet been developed. So we view the first effort of giving birth to all the sciences as premature.

But if we look at the planet earth and the solar system - as Newton showed - the first round of major details can be explained solely in terms of mechanics and gravitational force. Newton chose the right 'laboratory' to test out the body of a theory of physics. That gravitational mechanics goes a very long way to explain all the detailed questions on how any solar system's motions are to be accounted for. Elementary physics books in astronomy provide such details with great relish. We need only gross notions.

The solar system motion has gone on in essentially unchanged form for the past five billion years. The kinetic energies connected with that various planetary motions have been largely conserved. That is what such continuing motion implies. Also that momentum and matter has been conserved.

But equally remarkable is that the motion has maintained itself largely in one plane. This means that angular momentum (the spin) of the solar system has been conserved for five billion years. In our modern views, that indicates a remarkably isolated (and massive) system. It is a very long time between atomistic collisions! (As we will find out later, this isolation is a consequence of an expanding universe.)

This is the most rudimentary picture of simple mechanics.

We do not have a very good idea, yet, of what makes (or made) solar systems. It is very difficult to determine whether other stars have such solar systems. Stars are far away (we only see them as points). Planets are so much smaller, and they possess no optical luminosity of their
own. We cannot 'see' them easily. But present astronomical methods are trying to detect them by quite subtle means.

That puts more of a burden on physics to come up with explanations for the one sure birth we have, our own solar system. (If we could watch others being born, it would be easier to figure out the explanation.) Clearly the origins have to do with rather violent start-up issues a time ago. We date the life of our sun very close to that of the earth, with the notion that both started up out of the same violent events. The history of our galaxy is quite a bit older. And as we will indicate in galactic stories, there is a modestly known process by which stars are born in galaxies. So if our star was born in somewhat normal fashion, there were one or another plausible processes. Collapse of the central mass of an earlier star with a trail of droplets, due say to some external passing disturbance, e.g., a second star is a possibility. Or perhaps accretion of gaseous or dust-like matter from an earlier explosion. Or, as another interesting one, suppose an earlier star, normally forming, exhibited an internal instability with some angular characteristics. It might tear apart into two major pieces and separate (with droplets) with each piece maintaining its equal and opposite angular momentum. If you have a feeling for the constraints that the laws and principles of physics put on the problem, there is still time for you to invent your fairy tale. But note that the physical sleuths are sleuthing (with whatever evidence they can assemble) and one may expect that their planetary, stellar, and galactic stories of start-up will get better and more confining in the next decade or two. (The problem, as always, is not so much as to invent plausible stories but to find enough experimental constraints that can help narrow and select the best fitting one. For example, there is the constraint of the types of materials found in the earth and sun.)

The sun and solar system, and asteroid bodies that we are bombarded with, all roughly exhibit kinship to a universal abundance curve for nuclear species - hydrogen, helium, lithium, etc. Yet, as the recent transplanetary explorations have shown, this does not mean that each planetary body, or asteroid body has the identical composition and state. Loosely speaking there is a variation from the inner planets to the outer, there is segregation of materials shown in the planets too.

So there we have it, our sun and solar systems. A sun which can maintain its combustion process of nucleosynthesis, burning its nuclear hydrogen fuel to nuclear helium, its particular middling character is its particular size, defined as a unit solar mass (about a million miles in diameter), which for the burning process turns out to be a surface radiation temperature of about 5000°C, and a corresponding solar constant for its radiating power. Its series of planets do not have the gravitational strength to 'crush' and strip its molecular - atomic - ionic constituents to nuclear constituents (nuclei and electrons). (Although with the great size of Jupiter, that planet is not far removed from such crushing strength. Jupiter is thus hotter and more liquidy than would be true otherwise.) The other planets thus are 'cold' bodies, which take on their temperature from a radiation balance with the sun (with very little internal radioactive heat). We have indicated loosely that one can make a 'top of the atmosphere' calculation of the planet's temperature. Mercury, nearby, is obviously quite warm; Pluto far out, is extremely cold. The interesting trio, for our comparative purposes, are much more nearly far out - the 2nd, 3rd, and 4th planets - Venus, Earth, Mars and the earth's satellite, the Moon. We are the first generation of Man who has been able to 'look' close up. Those 'looks' have served as a check on our physical theories. It has added sobering physical restrictions to what we can surmise, and at the same time, it has provided us with more confidence in our ability to explain things. While conceptual horizon may have not expanded too much, the reality of what we can or cannot do has been augmented.
We get a sense of comparable age (in the five billion years range), of a comparable range of materials, of a comparable range of geophysical processes, of relatively rich geochemical processes, but - of little or no chance of biochemical processes. The latter two require expansion.

Our planets show a number of kinds of accretions - liquid bodies, solid bodies with very thin 'fluid' absorptive layers, solid bodies with 'dust' accretions (rings of Saturn), solid bodies with liquid and gaseous atmospheres, solid bodies with heavy clouds, solid bodies with subliming atmospheres (solids vaporizing directly, like carbon dioxide ice). We can find evidences for lost liquid accretions. Earth has a considerable liquid accretion; three-fourths of the surface is covered with water. There is evidence that most of these surfaces showed or show considerable chemical-molecular activity. This sort of property, we felt in our associations with NASA programs and investigators, was to be expected as a homeokinetic physics result. But we and many others were dubious about life. Active geochemistry does not assure active biochemistry. It may (we will discuss this later) if the proper range of atomic ingredients CHNOPS and the first few rows of small atomic ingredients, hydrogen say through copper, are available, but that then raises the question: if there is a universal abundance curve for nuclear constituents why are not all planets ripe for life? That becomes the specific question of the greenhouse effect. We are inclined to accept Hart's modeling. In the group of three planets, Venus, Earth, Mars, only Earth has the 'just right' parameters to hold an atmosphere. Thus it is suspected that Mars had early water coverage with large scale oceanographic and river runoff processes. But it couldn't hold those relative components - they boiled off.

We will add one more idea. If located in the right zone, a planet will not only develop a relative atmosphere, but it will find absorptive components to supply a useful greenhouse effect that entwines an isothermal atmosphere. And furthermore, that atmosphere will have a 'mild' climate, not too stormy, not too turbulent (thus Earth). It would have a rich geochemistry, partitioned among a solid, gas, and liquid phase. And that geochemistry could be extremely rich in the liquid phase. That such chemistry could move toward a rich hydrocarbon chemistry seem also to be true. The fact that this may lead on to life, we will save for another chapter. (Congratulations you were lucky.) Suffice it to say that top of the atmosphere temperature relates reasonably to surface temperature; atmosphere, hydrosphere, lithosphere, geochemical sphere (or zones), exist, and that a biochemical sphere (involving CHNOPS reactions) also exists, and even the evolution to life, leading to Man.

But the presence of so many fluids, couples the planetary motions together. Thus we find tidal couplings, which perturb planetary motions, and help govern them in very long runs. Spinning fluids drag on rotating solid bodies to stop them. There is some sense that the current twenty-four rotation of the earth is governed by atmospheric tides which trapped them into this particular period.

But there is one more piece of excitement in a physical earth. The lithosphere is not a big solid simple rock. Instead it reveals, in its inner structure, the conditions and characteristics of its original assembly. We surmise various properties for a central metallic core of perhaps 1500°C, and various specific rock type shells, making up a solid sphere (almost 8000 miles in diameter). As we approach the surface, we reach stony fluid-plastic like magma layer (of about 60 miles) with an asthenosphere cover. The 'modern' surprise (of the past ten years) has been the surface. It is a series of cracked apart thick solid plates, including those that carry upward to hold the continents. To some extent, one may view it as a caked and cracked mud flat, on a sphere, except that the plates ride over each other at their cracked edges.
The surprise has not been the liquidity, plasticity, and elasticity of the earth, but the specific form of independent plates. It is interesting that 50 years ago, a geological thinker Wegener (you can read his book On The Movement Of Continents) posed a startling theory of the plates, based on their current shapes, and a possible movement. What was startling was the detail with which the theory was developed. A colleague with whom we were associated with, lesser known, Paul Siple (geographer, Byrd's Boy Scout of the 2O's, gadfly in many environmental sciences) made a great point that there was a great deal of plasticity to the earth (as opposed to the more conservative view of a fixed elasticity), derived largely from earth movements and volcanic action. He examined a variety of what he claimed were not erratic cyclic wobbles of the earth's axis, angular momentum shifts generated by various periodic shifts (for example, a six-year correlation with earthquakes). He tried hard to interest the geophysical community in his notions in the 60's.

Finally in the 70’s, the notion of a plastic earth, based on elastic plates in restless responsive motion to underlying 'fluids' (more like plastic material-like 'flow' in rocks), took hold and all of these old ideas have become the physical story of an earth with a restless surface. Science news in the papers (and Scientific American) occasionally run articles as each new detail is found.

Thus drift of continents, earthquakes, spreading of ocean depths at plate boundaries, reasons for the uplifting of lands, and then followed by the wind and water and cutting and eroding action of dust and dirt begins to dominate the surface processes on earth (Scheidegger's Principles of Geodynamics, even though a little technical, presents a richer sense of most of the movements of the earth; quite rich even if he doesn't deal too much with the fuller story of plate motions that came to understanding after his book).

The story of a restless surface of the earth, and of the many processes that have been involved in putting life, Man, you into the now of your picture is one that everyman ought to learn about. It gives geography, geology, climatology, oceanography, hydrology, geochemistry a new perspective, a new meaning, and it ought to prepare Man for the notion that he must learn to live with that changing earth, for both him and other life species to survive. That life can survive without Man is easy; Man's survival is not so important in the scale of natural processes.
We intend to offer you a scenario, a time scale of processes, that may take your breath away (or it may leave you with a 'so what?' reaction). First let us offer you a different scenario. It is one that only fell into place about ten years ago. It was the start-up of the big process picture. It is called the problem of the three clocks. For a physical story to make sense, the following events had to occur serially:

1. Start-up of the universe
2. Start-up of galaxies
   2a. Start-up of our galaxy
3. Start-up of stars
   3a. Start-up of our star
   3b. Start-up of our planet
   3c. The first rocks.

Observation and theory, independently, for each event had to be derived to convince people of the validity of the big physical modeling. This meant, in particular, that general relativity was at stake, nucleosynthesis was at stake, even down to 'mundane' earth geology was at stake. Fortunately (for physics, for Man's understanding, for this book) the stories came out the time scales

1. 15-20 billion years before present (ybp)
2. 10-15 billion ybp
   2a. 10 billion ybp
3. 10 billion ybp
   3a. 5 billion ybp
   3b. 4.7 billion ybp
   3c. 4.5 billion ybp

(Don't hold your breath on great exactitude in these numbers, only in their essential consistency.)

We have recently come to the conclusion that it was timely to begin to organize the question of life's start-up. So we offer the case study of the following nine clocks (perhaps related to Dorothy Sayer's seven tailors).

1. earth’s assembly and heating up 4.8 billion ybp
2. plastic-elastic puckering and degassing of earth 4.7 billion ybp
3. condensation of water 4.6 billion ybp
4. formation of elastic plates 4.5 billion ybp
5. bucking into continents 4.4 billion ybp
6. geochemistry start-up (sedimentary geochemistry) 4.3 billion ybp
7. weather start-up 4.2 billion ybp
8. biochemistry start-up 4.1 billion ybp
9. life start-up 4.0 billion ybp

We do not insist that we are certain of all of the steps or their precise order; but we try to make the point that the start-up involves a very crowded agenda, and different from even two
years ago, we believe that the case can begin to be made that life is squeezed to appear on the
stage, on our planet, and has an obligatory character about it.

There are many lines of evidence that have encouraged us in that belief, not the least was
Hart's atmospheric evolutionary modeling. But perhaps we ought to try to tell a little of the
history of ideas on life somewhat more coherently.

In the 1920's, the Russian Oparin wrote a startling book (Origins of Life), which
proposed a purely chemical origin to life and some of the elementary steps that might be
involved. Somehow, he suggested, the capability of forming droplet or cellular organization
around water (liquid coacervates), and involving proteins and fats was a significant factor. In the
30's, the German physicist Schrodinger wrote a little volume What is Life?, which even if more
physically perplexing began to ask the question what does a living system have to do in order to
face physical law.

Meanwhile organic chemistry, more particularly biochemistry, continued to make
progress, which had been going on from the middle of the 19th Century, to identify the fact that
life's 'chemical' processes involved materials no different than materials that could be
synthesized from basic simple atomic and molecular constituents. And in particular, the giant
molecules, at the time looked at as colloidal particles at no certain molecular weight or
constitution, the proteins, began to be pinned down as chemical compounds involving very
definite constituents, e.g., by the 1930's-1940's. In fact, it began to appear that all proteins in
living systems were made of twenty smaller units of amino acids. Thus life's ingredients –
proteins (amino acid complexes), fats and oils (with basic lipid components), carbohydrates
(starch complexes of simple sugars), other simpler inorganic and organic compounds began to
emerge.

And then the climactic events take place. Physically Miller and Urey began to simulate
'early atmospheres' in a flask and with stormy weather of electrical discharges, and some
primitive compounds in solution, showed that natural processes could lead to amino acid
assembly. The building blocks of protein could 'easily' be produced in solution by 'easy'
energetic processes. (No seven monkeys and seven typewriters, etc.)

Watson and Crick took on the problem of determining the chemical content of genetic
material, whose expression could lead to protein. They showed that DNA and RNA (nucleic
acids) were made of four repeated fractions arranged in a double helix, whereby the story of how
DNA encodes and replicates or transfers to RNA which has capability, in a cell, to transform and
transduce and produce proteins emerges.

Then Miller showed the molecular structure of some simple viruses and how many would
be assembled.

The confluence of biochemists, biophysicists (the invention of the electron microscope
helped) and their theoretical interests produced the breed known as molecular biologists. A
physics and chemistry of life's process was on the march, becoming explosive in results from the
mid 1950's on.

Oh yes. Everyone began to take Oparin seriously (he has rewritten a number of editions).
From that point on, every few years, a serious meeting on the origins of life have been held. But
beyond the biochemistry of the problem, which certainly has to be a significant portion (we
would claim that the chemist regards it as the whole problem), there has been important moves to
a physics for the problem. We will tell you some of the pieces that intrigue us.

Harold Morowitz (a biophysicist from Yale) at a 1969 Biophysics Congress, in a session
on the origins of life, made the following intriguing point. (We were associated, via independent
biophysical programs, under NASA support.) The thermodynamics of life cannot be based on a thermodynamic heat engine (we will describe machines and engines later). They require reservoir sources and sinks very far apart in temperature. (For example, the automobile engine involves high temperatures at the 1000-1500°C level.) Whereas life works almost isothermally at environment temperature. But it had to be a thermodynamic engine. What potential source was available to run such an engine? He suggested that it had to be photochemical (the kind of energy by which photosynthesizing plants, using a material like chlorophyll, makes use of. It is interesting to note Kettering explored chlorophyll as an energy transforming source in the 1920's at General Motors, with a view to understanding its basic action). Photosynthesis, Morowitz pointed out, depends on the photonic source, the sun. If its surface temperature was too hot or too cold, it could not provide that photonic energy (see our later discussion on the energy of photons) that would fit. Life could not work. That notion very sharply delimited life to a small middling range of stars, only the neighboring categories of stars, near our sun’s size, that were only a little redder or bluer than ours. This was the first time that a central piece of physics had been tossed at the problem. Progress in the straight bond chemistry and catalytic chemistry of life then could be fitted in together within a more intelligible thermodynamic construct.

Meanwhile the structural, morphological internal details of the operation of the cell began to be clarified - those with central nuclei, those without (the later eukaryotes, and the earlier prokaryotes). The organelle factory machinery in the cell's interior began to be understood. Its fantastic complexity began to be understood. The road maps of all of the long chain complex metabolic (energetic) biochemistry began to be understood. The existence of small energy chemical engine steps (allosteric reactions) began to be understood. The trouble was that while many of the steps on the way toward unraveling the story of life was being made, the complexity of branching and the mappings seemed to have as much complexity as going from cosmology to fundamental particles - and capable of being packaged on the heads of pins.

But those less inclined to throw up their hands in horror worked on pieces, and some worked on integrative steps, and the problem has not seemed to present such a long impossible chain. After all cells beget cells. Cells are wrapped in lipid membranes (a double layer of lipid, polar molecules that are fat or oil ‘loving,’ and water ‘hating;' this characterizes how the molecules orient because of electrical properties, not emotional responses from a 'brain' - but we can characterize it as their 'brain' or command-control process, a rather stereotyped response. Why this language - of love and hate? Because the kinds of processes that are identified with this language is really going to arise, in the end, from such processes). In mosaic fashion, there are globular proteins (entwined balls that have developed from long linear protein chains) which ball up and are attracted to and position in the lipid 'oil' layer. Their immersed girdles are oil 'loving,' their exposed faces are water 'loving.' (All of these properties are elaborations of what you find in oil-water mixtures, which exhibit droplet forming properties. This is one of the aspects that Oparin was talking about.) Many of these mosaic protein balls have admission holes into the interior of the cell. These are gates which have electrical characteristics. They are selective in what kind of small molecular or ionic constituents they admit. This gating (which we identify formally as a bulk viscosity, controlled by the cell as a factory process) is a basic component of an engine process by which the cell runs its internal mechanisms. The fundamental engine processes involve multiple stream flow processes (osmotic processes) under control of internal organelles (factory stations). The conservations? As usual, matter species, energy, momentum or action modes. We will spare you the internal factory details.

But then again the physics problem: How could such complex cell factories start-up?
One clue, on the way, has been the following question: It has begun to be pressing from the 60's. How does one make a chemical oscillator, a cyclic engine process, without involving too much machinery? One well developed way was the chemo-mechanical means used in the combustion engine. Make chemical combustion energy available intermittently (with valves), absorb the energy mechanically in a rotating fly wheel. But can one make a nearly pure chemical oscillator, say one with no macroscopic moving parts? A story of possible answers began to emerge. For example, Kalchalsky pointed to the significance of common clay as a reactor bed for step by step chemical processes. The clay pore can seal depending on acidity. If it fills with a reaction whose acidity changes, that process can relax in the pore; the pore opens, recharges, closes, reaction relaxes, etc. He showed the process perhaps not forever, but it would begin to chug along a number of times. We saw another example in which a high pressure reaction in an industrial process cell heated up, blew itsblanketing fluid cover, stopped the reaction, reformed the blanket, started up the reaction by the heat, heated up, blew, etc. But gradually reaction-diffusion has begun to appear as the central theme. Reaction at one place is confined, it diffuses to another, is confined, it diffuses to the first place, is one such model.

So an entire formalism of stability of chemical reactions has appeared. You may have seen an iceberg tip of the issues in popular attempts to evaluate Rene Thom's so-called catastrophe theory.

Meanwhile chemical stability theory goes along.

So out of this welter and miasma of problems and processes, we would like to turn back to our primitive schedule and some primitive sense of what we would like to suggest might have been involved in life's start-up process.

We are inspired, as we said, by Hart's atmospheric modeling, and a new theme of Morowitz'.

After Morowitz characterized the solar source, he went on to characterize the energetics and probabilities of all of the elementary one or two step reactions involving the simpler atoms, e.g., C+O, H+O, C+N, etc. The question was the probability of more elaborate complexing. Morowitz is a strong believer in the basic chemical physics of the start-up processes for life. But after a number of years, he has finally achieved a sense of a class of chemical reactions that have rich branching steps. Here we share with him a sense of excitement and appropriateness. Much of the issue of complex systems, including life, is to find processes that lead to rich branching possibilities rather than dead ends. Life, as the cliché says, must go on (for all viable systems).

Hart has a rich chain of atmospheric processes. We put these together with our ideas.

The important thing about life processes is the scale at which the process will come off. We see the need for a reactor bed that nurtures prebiological processes, before they can run and 'start-up' as an autonomous cyclic process. We had not been able to find the appropriate reactor bed. Now we have one to suggest. We suggest that life (organic biochemistry) follows, obligatory, on a characteristic geochemistry.

In our earlier tabular scenario, we ask attention to the emergence of a sedimentary geochemistry after oceans, lands, and rivers have started, and very nearly with the start-up of weather. In particular, we ask that consideration be given to sedimentary beds laid down at the interface between fresh and sea water, with an interface exposed also to a primitive reducing (carbon dioxide) atmosphere. Weather, it is becoming increasingly known, is tied to the oceans. We are interested in the existence of storms in the youthful atmosphere, particularly with regular periods. We submit that there is ample reason to believe in periodic back and forth movement of a saline interface in the sedimentary layer. There is no life chemistry, but there is a rich
geochemistry. That chemistry, particularly a rich ion exchange chemistry, with an atmospheric chemistry and its periodic creation and delivery from the atmospheric stirring storms, will create a rather rich hydrocarbon chemistry (Hart tells us) which can be fixed, by the atmospheric processes to form higher organic complexes. In the ground layer, metal-organic complexes of various kinds can be formed.

We regard the sedimentary layer (or its surface) as furnishing the kind of multiple scalings that an autonomous chemical engine process can emerge within the sediment. We regard the process as a natural 'fractionation' column, a reaction-diffusion bed, or an exchange bed, in which a cyclic scale can be found. What sort of scale? One that likely locks in on a day-night variation in water and storm tides. Less likely would be a slower yearly cycle, but we wouldn’t exclude it. That prebiological engine is not imagined run with a lipid membrane. The engine 'membranes' are electrical bilayers that develop as 'batteries' in the ground layer.

Then subsequent encapsulation by oily bilayers may take place, and ultimately an autonomous 'cell' evolves to where it can motor out with some independent life, not far removed from its sedimentary 'womb.' Other component processes, more internal machinery (engine building an engine), rich internalized chemical chains, metabolic engine and replication duals, onboard engine processes, then might follow in sequence.

Is that much of a story? No. Just enough, hopefully to stir the imagination. Life, we are saying, forms in a reactor bed with sedimentary earth, near surface interfaces.
Chapter Twenty - On the Organs of the Body

When one comes to the body, the specific bureaucracy that makes up the system, e.g., the mammalian system, is given. Your command-control rule does not have to design that bureaucracy or linkages of the engines and parts of the body. The archaic potential of the genetic code took care of that, epigenetically developed within the environment of the mother's womb, subject to all the vicissitudes of that field (but with lots of carefully designed protection. Seldom was earthly king child so carefully nurtured as in the prebirth of the living machine).

Structurally, the body is made up of cells, arranged as organs - brain, liver, G.I. apparatus, lungs, muscle, connective tissue, nervous system, cardiovascular system, secretory glands, skin. Functionally, the body operates at a number of functionally hierarchical levels. At the lowest level, the organism is not a nuclear machine. The lowest level constitutes atomic streams. There are balances and storages (depots) for CHNOPS (to use a well-known acronym - carbon, hydrogen, nitrogen, oxygen, phosphorus, sulphur), as major atomic ingredients, another dozen or so significant elements (Na, Mg, Cl, K, Ca, Fe), and a few dozen more trace elements. The mammalian 'cocktail' has to be so fully designed. There are peculiar and surprising defects even shown when each of the trace atoms are not there. Our careless connection to the real earth generally makes the traces 'easily' available.

But as we suggested earlier, systems seldom operate their inputs and outputs at low levels of association. Since life is related to and relates to the formation of earth's chemistry (geochemistry and biochemistry), it is not surprising that common levels seldom descend below characteristic molecular constituents and fragments. Thus one commonly thinks of oils - fats - lipids, sugars as carbohydrate fragments, amino acids as protein fragments, water, minerals, vitamins. At this level, the location of structural depots or segregation of the molecular fragments or complexes among organ subcomponents (typically cellular components) is more apparent. Details are pursued most interestingly here by actual study of cellular chemistry. We have not elected to describe the cell as a factory. Scientific American literature has done that with sufficient elegance (Readings on the Living Cell).

The molecular processes become more interesting when they relate to major ingredients that the internal organ system operate in, rather than the input products (or even final degradation output products) that system takes in, processes by partial breakdown and storage. A non-exhaustive list of these molecular constituents are oxygen, carbon dioxide, water, glucose, free fatty acids, lactate, pyruvate, sodium chloride, about 20 hormones, nervous transmitters (adrenaline, acetylcholine, others) carbonate, a very great variety of proteins and protein fragments (peptides and amino acids).

These materials are caught up in a large number of processes. But, it turns out that most of these processes (immunochemistry) are involved in making body parts and recognizing foreign protein substances (these commonly represent invaders of the body). Note the remarkable process, different from ordinary Man-type engineering. The same processes and forces run the body, as well as build and maintain the structure. 'Brick' and 'mortar' are not laid forever. That maintenance processes takes most of the chemistry. But if we turn away from that rather overwhelming chemistry, we are left with perhaps a dozen major chemical process chains, involving relatively simple chemical ingredients. This may be regarded as the more operational, lesser bureaucratic functions. In any case, if you classify many of the observed functions, we can see how they are associated with organs. And if we watch organ interaction, we can finally discern what a mode of action is, and why we call it a mode. A mode becomes a characteristic
pattern by which the operation of the organs are temporarily coupled together. In these modes, we can then surmise the chemical flow streams that are related and involved in the coupling. All these processes run as cyclic thermodynamic engines. Thus we find standard conservational variables inside the body's fields, and the consequences of those cycle processes.

We might start at the bottom of the cellular process and inquire what runs the cell. The answer would by differences in chemical potential (gradients). Without any contradiction of the laws of thermodynamics, such living entities (cells) move (motor act) to acquire chemical potentials (by ingestion) which can then power these processes. The living system does not have to make the primary chemical potential. It acquires them from potential storage depots outside. It is just like the motorist who drives up to a gasoline storage, pumps up the gasoline, and can then afford the energetics obtained via a chemical combustion engine to power all necessary processes.

The basic engine process develops as osmosis - a control of the flow streams across bridges which separate chemical potential differences. If you can do that, you have made a chemical engine. That is what life basically is.

In its more complete and complex form, we have "defined 'life (see Iberalll, McCulloch) as a complex of coupled thermodynamic engine cycles which cooperated to dynamically regulate the internal state of an organism independent of vicissitudes or changes in the external environment's, that this dynamic regulation was achieved mainly by inhibiting or releasing from inhibition (declutching) the operating state of these engines. We stated that the command-control system was also one additional engine process. The notion of regulation of the interior was made the central doctrine of physiological theory by Claude Bénard, and named homeostasis by Cannon (The Wisdom of the Body). Since this did not identify the general mechanism for that regulation, when we identified it as dynamic regulation of thermodynamic engine processes, we referred to such regulation as homeokinesis, the dynamic or kinetic regulation of engines and their flux streams. It is the generalization of homeokinesis, as the general regulatory process of all complex systems that permitted us the identification of homeokinesis, or homeokinetic physics, as the basis of operation of all complex systems. As we have tried to indicate, we try at no point to contradict standard physics of simple systems, only extend it to the complex of thermodynamic engine processes that we find in interiors.

What are the implications and consequences of that point of view? These were the first questions we explored experimentally when we started to explore this subject a generation ago.

The point of view means that you will find an extensive spectrum of dynamic and cyclic processes for every material component, process, operating structure, and mode in the body (except for the nonperiodic birth and death - the singular events of the individual; but if attention is transferred to the species, again the cyclic engine nature appears).

Clearly the heart beat, the respiratory breath are well discerned cyclic processes. So are brain waves (EEG complexes). So is the regularity of model behavior, for example, of sleep, menstruation. But it is the ubiquity of dynamic cycles, and their purpose which is unique in our construct. Their purpose is to make the life process come off.

So we started to look in the measurement of metabolism. We said the body had to be an engine, a process involving a cycle longer than one breath (because in one breath oxygen is taken in for combustion, and carbon dioxide is released as the combustion byproduct - this idea was an alternate to the idea that the very many individual cells were the engine, even if they were individual 'cylinder' firings). Further, because of the relaxation time of the body (suppose we
put an engine on a test block, we can estimate how long it takes to ‘warm’ up), the engine cycle had to be less than three hours, nevertheless there had to be a three hour duty cycle.

In essence, we were saying that if the body was working all the time, there were only three ways a powered system could be run: (a) there might be power supplied from outside ‘by wires’ (no wires except sometimes small energy external commands); (b) a preprogrammed package (there is a low energy genetic package aboard); or (c) an onboard prime mover engine. Lavoisier had shown, 300 years ago, that the body worked by an equivalent oxidation chemical combustion engine:

- fuel plus oxygen reacts to form carbon dioxide plus water plus other combustion byproducts plus heat plus work

Since the first two were not likely sources, we had to find a cyclic process engine that would permit the lively changes in duty cycle and action modes, e.g., from rest to movement to work. So we went to work to measure the heat production and the oxygen consumption and the carbon dioxide production. Those we could easily do from outside.

We found our engine cycles - a two minute, a seven minute, a thirty minute, and a three and one-half hour cycle. Thermodynamic reasoning was vindicated! We then went fishing into the interior, to look at the internal streams. e.g., the blood gases, the blood fuels, where the exchange processes take place. Let us illustrate by characterizing very superficially the action of some of the organs.

Blood is pumped periodically (each second) by the heart as a squeeze pump. That blood enters the arterial system where it is carrying two potentials within the stream. The pumping against resistance, by the heart muscle (powered by a chemical engine source in the muscles), develops the potential of pressure, capable of forcing the flow streams through the very extensive arterial tube system. Also a separate part of the circulation passing through the lungs supplies a carrier in the blood, hemoglobin, with a chemical potential of oxygen, in the form of oxyhemoglobin (carried in the red cells. The red cells are made in the spleen factory and injected into the blood stream where they have a monthly life cycle and are then removed). The blood with its two potentials, one mechanical, one chemical, passes through porous capillary exchange beds located in all tissues throughout the body where these very thin pipes with porous walls leak out and into every cellular region, and bathe the cells with oxygen and nutrient. The exchange process is a marvel of engineering using the osmotic force developed by the chemical potential difference of protein containing blood plasma and nonprotein containing blood plasma. Inside the capillaries, the blood carries protein (such as albumin). Outside the capillary there is none. There is another scavenger system, the lymph flow system, which cleans up any small amount of protein that may leak out.

Passing through the capillary, blood exchanges the oxyhemoglobin for carboxyhemoglobin. That is the carrier sheds oxygen and picks up combustion carbon dioxide. That passes back through the venous return system, at low pressure, back to the heart where it is pumped up again and exchanged for oxygen chemical potential and mechanical pressure potential. That voyage (an excellent thriller motion picture was made of such a voyage) takes about 10 seconds on the average, to make the circuit.

One might draw the notion that some processes were uniform, others periodic, cyclic. That becomes a matter of watching for both very much shorter times, and longer times. We were naming some of the operational time scales in passing.
But note when the oxygen - carbon dioxide exchange takes place in bathed organs, suppose muscle tissue, we implied that a combustion process took place. Smoothly? No. There was the two minute cycle. We implicated the cycle as run from the oxygen end.

Note that a combustion engine cycle could either be run from intermittent fuel pulses, oxygen pulses, or combustion byproduct pulses. The automobile engine runs from fuel pulses (cut off of input per cylinder). Air is pulled in and proportioned to fuel. In the body, oxygen is pulsed in by the capillaries, we found, which 'flares' the engine locally each two minutes. We found the 'engine' process to begin by how capillaries admitted red cells to the local region. Our explanations are still controversial. Actually that cycle engine processes are involved in all body machinery is still not widely understood and so is controversial. Details in any specific location is even more controversial. But if one accepts physics, there is no other possible explanation.

Many of our findings have been repeated, even if not widely known. In any case, except for the amount of detailing for any particular process, a spectrum of periodic processes is loosely assigned to each material and organ, and complex operation. These are run as thermodynamic engine processes. (We have offered speculative models for the various engine cycles we have measured.) An era is starting in physiology, in which these homeokinetic mechanisms, both biochemical as well as behavioral, will be identified in great detail. Welcome to the ground floor of that homeokinetic picture.

So briefly, in review of other organ function:
- liver - storage and manufacturing processor of sugar fuel from raw forms.
- kidney - a pressure filter for poisonous molecular complexes that develop in the blood; at the same time, the kidney filter retains body water (one may read one of the most engaging books in biology, Smith From Fish to Philosopher, on the kidney).
- muscles - chemical-mechanical converters which keep the body warm (in 'idling' performance), or alternately do work (lift that barge, tote that bale).
- brain - a converter that programs or initiates modal performance in other organs, and controls sequencing.
- hormonal glands (pituitary, pancreas, adrenals, thyroid, gonads are main glands) - most commonly, in parallel to the fast electrical processing of the brain and nervous system, which forms a net at least as ramified as the vascular system, the hormonal system dumps slower chemical messages into the blood, ‘to whom it may concern' messages, which when they finish their cyclic transports support the faster nervous signals as followers; or they have their own slow independent timing (you got mad at a driver? That fear-fight-flight reaction that you initiated in a tenth of a second in your electric nervous system is being paid for by open capillaries induced by adrenaline as a follower to support your mind. But you note you are now tired).

A nice introduction to what is inside and how it all works is Grobstein’s The Strategy of Life. For the brain we have already suggested that you might look at Elliott (The Shape of Intelligence).
Chapter Twenty-one – On Metabolism and Nutrition

(Should be excerpted or modified from Gene’s metabolic piece.)
Chapter Twenty-two - The Cosmos

Weinberg (The First Three Minutes of Creation) has told the story of the creation of the universe, as we believe it today, with such elegance that there is no point in repeating it with much detail. (Does that mean that physics will not change its views again and again? Not particularly. It means that a view has been forming for the past 4000 years of the universe and its character. Some notion of stars and their remoteness only began to form in Aristotle's time, and a physical science of processes in the universe began in Newton's time. It has converged, in less than the past hundred years to reasonable models of the large organizations beyond our touch - but not our sight. We may change detailed views, a number of times, to some extent, but change in the physical view will be very slow in basic outline.) It is the story of the 'big bang.' If you want to read a more primitive form of that story, as Gamow initially formulated it, read Gamow's The Creation of the Universe.

The story involves the same sort of potentials and conservations that we have been using, in fact essentially the same as for stellar processes (although the processes are run backwards) - mass, momentum, energy, angular momentum (conservation of spin), and electric charge. In the more mundane systems we didn't make much of the latter few, because they were hidden (balanced out) or they had dampened out. (A conservation of angular momentum in our solar system, one that has lasted for five billion years, is hardly trivial; similarly with regard to the spin of the earth, or why we have winds, etc. But we have taken care of the issue. Here in the cosmos, there is no hiding place, so we have to face these conservations directly, each on a par. So twenty billion years ago, there 'suddenly' appeared a compact assembly of very very hot radiation, photons if you will, with a temperature of about a trillion °C (10^{12} °C. If we were to represent each dollar by a °C, then there were as many degrees or dollars as in the gross American national product. Big numbers, but ones we can grasp. The sun's interior is only 20 million °C, rather than the million degrees of start-up). That radiation develops a very large pressure, which blows the radiation apart, so that it expands in a spherical-like manner. (Don't ask where the radiation came from, or how. It is not really known at present, although it has been possible for a number of physicists to conjecture. Very likely, one of the conjectures will get it right in the near future, as more focus is placed on the problem and the acquisition of pertinent experimental data. Data, for example, from very far out in the expanding universe has only accrued in sufficient amount to test various physical 'predictions,' predictions of general relativity, in the past ten years. Please allow some time to gather facts.)

Just as nucleosynthesis made energy from matter, from the mass defect of bound matter, so radiation energy, as it cools off, can make matter. And so a rain of material, protons, electrons, neutrons can begin a little after the pure radiation expands - just like a gas - and cools off. That happens below a hundred billion °C (10^{11} °C). Then, as Weinberg describes, various physical processes modify the products, and by the lapse of 'three minutes' we are off and running into the modern era of a balance between matter and radiation. But they are decoupled. They are no longer in perfect equilibrium as a vapor in condensation equilibrium with its liquid. One could say, as a metaphor, that the 'humidity' of radiation was thereafter less than one hundred percent. Photon 'vapor' could only disappear when it encountered matter.

But, thereafter, that is all there is to the cosmological process. Oh yes, we haven’t told on how fluctuating instability in the radiation-matter field might create galaxies, and more locally, by hydrodynamic shock waves, start up the opposite burning process of making stars, and via their processes make heavier matter - all of the bound nuclear forms that interest us, such as hydrogen, helium, lithium, beryllium, boron, etc. But those stories we have told elsewhere.
Second generation stars form from first generation exploding nova and supernova stars. And how planets are born.

And we haven't told you how the story comes out. That you deserve to hear. As that radiation, converting to cold radiation and matter (via local hot spot burners) process continues, finally the gravitational pull (there all the time, but too weak with the little amount of matter) begins to bite and tries to pull the matter together. If there is enough matter density for that bite to take hold, it pulls together, and, as we showed for stars, heats up the matter again, until it gets so hot (actively in banging kinetic motion) that it cracks up again and strips and 'melts' and goes back to radiation, back to a next 'big bang.' We now know that if such a cycling process took place (just like a pendulous mass-spring which transforms kinetic energy of motion to potential spring energy to kinetic energy, etc., radiation goes to matter goes to radiation goes to matter, etc.), it would happen with a cycle time of about a hundred billion years (remember we are ‘only’ twenty [14 is new number, NR] billion out from a start-up). But, within the past few years, we have found that there may be a density discrepancy. If so, and it is not yet absolutely clear that it is so, then this universe only started once, expanded, and will go out as a cold whimper.

One such process, physically-philosophically we cannot conceive of being, with one start-up of time and one end of time. So the next round of physical conjecture has started. Ours, for example, is most plausibly there are 'other' regions (not in our space) at which 'intermittently' (at cosmic times) other 'big bangs' start-up (or perhaps behind all such processes there is a God. Note that the function of physics has been to find more local general explanations for phenomena. Whenever a mystery can be found for which no 'local' explanation can be found, then it is fair enough to invoke God. One must note that a God that was non-interventionist in our universe was originally postulated by the very religious Newton. If this and other conceivable universes cannot be explained by the parsimony of physics, a science of motion and change, then the alternate hypothesis is feasible. However, note, since Newton, we have turned the issues to very large scale 'real' phenomena - solar systems, stars, galaxies, energy and matter production that support the existence of a universe. It is just 'final' origins and 'ends' that tend to confound us. From the time Man discovered magico-religion, as a problem in his own mind, that kind of command-control freedom, flow of authority from above has puzzled him and will continue to puzzle him regardless of how many layers in the onion of existence he peels off. Unless he reaches a last layer. That issue, philosophically begins its deep discussion with Aristotle (see his books "an Physics," "On the Heavens," and "On the Generation of Corruption").

In physics, most physical scientists await the next episode in this serial story, with the same eagerness that an earlier generation the serials on the Perils of Pauline, The Mark of Zorro (or Galactica). The outcome doesn't particularly affect what happens 'now' to us; it can possibly affect us the way we understood some things 'now.' Most physical scientists would prefer their science to be clean, secure, solid, straight-forward, and simple. So we still have to do some betting on the outcome of this 'horse'(?) race (better, this race between matter, energy, time, and gravity). Radiation energy blows us apart, matter pulls us together gravity provides the bond, then passes. That is not a very complicated story. (And if we succeed in taming fusion, in putting it in an enclosure, and making it a thermodynamic engine process, rather than just one hydrogen bomb big bang, then we will have shown a real capability of taming some of nature's most awesome processes. Admittedly it is 'only' the process makes a star go, but it didn't take us so long to get there, hardly more than 200 years one idea for this time.)
In any case, you are you, and you are weighty and full of substance, you think and time passes, because all of the large systems in the universe above you have authority over you, and all of the smaller systems in the universe (at least those in your locale) pass stuff and information up to you. Island you are not. As we have said perhaps even the universe is not completely an island. But the only things count are the local conservations and the potentials that have authority. They bind all.
Chapter Twenty-three - Galaxies"

You may feel more comfortable if you knew how, from the cosmological story, the structure of galaxies arose. It is not that you are necessarily so interested in galaxies, as you are interested in births, start-ups. You need not chuck a galaxy under its cooing chin, but where, how, or why does it come into being? We will not tell you too complex a story. The reason is that the exact story is not yet certain. Galaxies, as islands of billions of stars, have only been known since perhaps 1929, when the large telescopes and the persistent study by astronomers (Hubble being a notable pioneer in galactic study) finally identified their forms, independent of the apparent isolation of stars. Note the distinction: Stars are isolated bodies whose diameters may average a million miles. They are separated by a few light years (the distance that light travels in one year). Galaxies are made up of billions of stars. Their disc diameters may be a few hundred thousand light years. They may be separated millions of light years apart. That is the sort of large scale that is to be found in the universe. Our galaxy we see in the sky as the relatively bright streak of 'star dust' that we call the Milky Way. Why does our galaxy have that appearance? Because the galaxy is essentially pancake like, with pinwheel 'gas' streamers at its edges. So we see it most densely as a cut through the pancake, a broad streak in the heavens. We are out about one hundred thousand light years from the center of our galaxy, children of a middling star, one of billions. A neighboring galaxy to ours is the elliptic (tilted pancake) cluster that is known as Andromeda. It can be seen with a low powered telescope as a small elliptic 'body,' easily mistaken as a star. So that is the scale of things out there now.

Twenty billion [14, NR] years ago, that system of bodies was much more crowded. Perhaps we should say, not at the time of the big bang start-up, but a million years later. A complicated series of events were responsible for the formation of a first generation of stars and galactic clusters, which produced most of the heavy elements in the universe.

The main story we wish to extract from that start-up period, is that regardless of the mechanism of the instability - and there were many possible competing mechanisms (force systems, even if only based on the four known forces), which is what creates the difficulty in picking out the right one - density fluctuations, condensational instabilities, arose and formed both stellar condensations and galactic condensations. Which came first, which was the chicken, which was the egg? (Remember there was no 'genetic' code, only possible action modes. We simply are not fully aware of all the action modes of these newly forming giant systems, or better still, we are not fully aware of the preferred order of modes.) A good guess, perhaps the best, perhaps not, is that both processes could take place.

One plausible story is that basically there appears to be two shapes or kinds of galaxies - the spiral galaxy, most common, like ours, and elliptic galaxies. (There are further variations. A Scientific American article by Arp in January 1963 presents a good story of their forms.) There is the suggestion that these two types started up by different processes. In one, stellar dust accreted by gravity as a fluctuation matter condensation to form one type of galaxy; and in the other, early generation stars formed first as an instability fluctuation, and then accreted to form galaxies. In any case, gravity and angular momentum, and matter were the dominant processes and forms making up the inhomogeneous fluctuation.

This gives the quality of galactic formation, and galactic operation. The details within the galaxy relate to the internal electrodynamics hydrodynamics (known as magnetohydrodynamics) of radiation and gravitational matter, and its dissipative coupling to angular momentum. Time scales? A hundred million years per rotation; a few young stars born each year; average star lives of the order of ten billion years (the young large ones die quickly).
Chapter Twenty-four - Nuclear and Fundamental Particles

Some of you may have read the novel about the worm, Ouroboros, who swallows his tail and eats himself up. To those of you, it may come as no shock that what supports the large scaled processes in the universe are the small scaled processes. But peasants always support kings. All flatland physics has atomisms (or peasants) below, a system of processes and relations in between, and authority (from larger systems) above. Solid walls for example, or large scale forces have that kind of authority.

So you are organized as cells and organism - or organs and organism, or biochemical molecular complexes and organism. That depends on how many morphological levels you wish to identify and how you manage to trace the mechanisms of condensation.

In similar fashion, if we jump to the entire cosmos, and recognize that there were all these intermediate levels of clumping or condensation - galaxies, stars, planetary accretion, various other galactic processes involving gas, liquid, or solid phase transitions and dissipations of energy on top; or nuclei - atoms - ions - molecules below – nevertheless we can ask the question how are the very top and the very bottom related without having to repeat (or tell) the story of every level in between. Note, for example, we most often like to tell the story of history through the eyes of elites, making an implicit assumption that their actions equipartition loosely through the peasantry (they roughly do, if the elite gets things organized enough).

So we jump now and ask what is the relation of cosmos to nuclear particles? If you want to be more precise, there is some variation with distance from the center of a galaxy of the nuclear constituents, but that variation is relatively minor and a detailed study for physicists.

The remarkable fact is that essentially everywhere we look in the universe (and we have many ways of looking, perhaps a half dozen), we find the same nuclear abundance, relative for one or two nuclear species, absolute for most others. Remember our story is that heavy elements were made quickly from a first generation of stars which prepared the slower burning second generation. One recalls that the initial big bang produced protons (hydrogen nuclei), electrons, and neutrons (unstable combinations). When this material accreted to form stars, the hydrogen nucleus (protons), or deuterium nucleus (one proton plus one neutron, much more stable than a solitary neutron) was burned to form helium nuclei (two protons plus two neutrons). Thus the age of stars is largely given by their ratio of hydrogen to helium. The other heavier nuclei were made by a fancy variety of hotter burning processes in young stars, and when they exploded, they produced the characteristic abundance that we now find with heavier nuclei, that is the abundances that we associate with lithium, beryllium, boron, etc., up through uranium. That universal abundance falls off loosely with increasing nuclear weight (with a wiggling in classes) and essentially levels out at higher weights.

The fact that physics can develop a theory that accounts for the manufacture of nuclei, and their abundances, means that, loosely speaking, we have the stellar process right, and the story of two generations of stars right in galaxies. Again, it is the historic story of galaxies that is still weak.

So what do we find in the universe? An essentially fixed relative abundance of heavy nuclei, variable amounts of hydrogen and helium nuclei, electrons. These combinations are bound often into ions - atoms - molecules whenever the temperature is not too hot (over 10,000 °C) to strip all electrons off, and not radioactively exchanging photons from any residual 'hot' processes.

But the higher weight nuclei are not stable. Depending on proton-neutron combinations in the nuclei, they have greater or lesser instability. Thus nuclei above a certain weight are
unstable. Even if or when they are formed, they break apart, spontaneously, at some rate, to form more stable nuclei. That process is known as natural radioactivity. Some of those breakdowns are so infrequent that they furnish long term atomic clocks, measuring radioactive time decay of time scales up to billions of years. So we use them as clocks. There are a few points of view that can be taken of that decay. The standard one is of a quantum mechanical process. We have a point of view that regards all clocking or engine processes as diffusions, dissipative processes, in such internal cases as internally dissipative (or bulk viscosity) processes. In some significant way, Weinberg and we appear to share that view. As he puts it "In each cycle (of a cosmological oscillating model) the entropy per nuclear particle is slightly increased (its order is decreased) by a friction known as 'bulk viscosity' as the universe expands and contracts." We will not dispute any apparent difference with the explanations of quantum mechanics. Instead in more technical literature, we present arguments for a common explanation. Be that as it may.

And so the universe is filled with one more kind of material, a material which is evanescent. Since there are so many kinds and scales of processes going on, particularly at galactic scale, there is a very large range of kinetic energies available in the various particles. One finds relative velocities up to near the velocity of light. What happens when such highly kinetic particles collide? They break up nuclear particles. Fine. Does that produce 'only' debris of the proton, neutron, electron, and exchange photon type? No. We begin the deal with energetic processes, that are 'hotter' (as collisions) than 10-20 million °C (107 °C). They get up to 10^8-10^9-10^10-10^11 °C. But those are process scales like those we did not detail in the first three minutes of big bang creation. However, note that these processes are only a thin noisy background in whole galaxies, not the whole process that they were in cosmic start-up.

So we find a very extensive galactic 'noise' background, of what is called cosmic radiation. It should be called, and gradually is being referred to as a common galactic radiation. (The cosmic background radiation is a more common low temperature radiation of about 3 °K, as a remnant from the big bang expansion of the initial radiation. This has recently been in all the papers.) That cosmic radiation is the fragments and pieces that result when protons, electrons, and photons (their key fairly long lived components in nuclei, atoms, and their slow exchange processes) of high energy collide.

That opens the Pandora's box of so-called fundamental particles. As time went on, from the first discoveries of additional particles in cosmic radiation, or in atom smashers (the result of David-like sling shot machines that smashed particles together to break them), of positrons, and neutrinos, and mesons, and many other strange particles, either a chaos of hundreds of 'particles,' most with extremely short lives measured in very, very minute fractions of seconds (e.g., 10^-16 second), had to be lived with, or some simpler schema had to be found to 'explain' them all. That is the process we are in now. Hopefully, for the last time (but do not hold your breath), since the 1960's, a scheme of point particles has evolved, of two kinds of point particles - leptons and quarks. At present six leptons are suspected or believed in (their names? Electron and electron neutrino, muon and muon neutrino, tau particle and tau neutrino; also antiparticles. (Say "How do you do. ") There may be six quarks - given quixotic labels of up, down, strange, charmed, bottom, or top 'flavors.' These are subject to special conservation rules in addition to the ordinary rules macroscopic rules found in complexes of particles.

It has become fashionable in the lay press to try to run out the lepton-quark player-game story for all to see, in a thousand words or less. The efforts are nonsense. The explanations required or offered are at the frontiers of physics, straining the comprehension of the most
learned, the most skilled in the process. 'Common man' explanations just garble the possible outcomes.

So at least you know of the current stack of likely candidates. Among the standard 'permanent' game players, only a few of the leptons and quarks would be involved. The others are required to handle the more exotic, short lived particles.

But the main points for the layman, are that the proton has been found likely to possess internal structure (not the electron which appears to be point-like). Its possible internal structure requires an effort of explanation. Thus quarks and exchange gluons are the current attempt of explanation. The story is going reasonably well, and the next few years will see if it holds up. (Gravity force is believed to be created by the exchange graviton, as yet unproven.)

The other basic point is that these 'fundamental' particles are points. If that continues to hold, they can have no further structure. A singular rock bottom (except one) has been struck. The only thing that could exist below is a continuous 'ocean' in which these points are anchored. More of that later.

So it may turn out that physics may have reached its bottom; or it may turn out that the current round of lepton-quark explanation is bad (nonsense is too strong a word) and has to be modified or replaced; or it may turn out that a next round of complexity has to be opened up. Why are we so dumb, and uncertain? Well, the smashers in use now get up nearer and nearer to the first start-up of the universe. We have gotten to that story only in the last 20 years. Let there be a little time for some further learning. These are two companion piece mysteries - what happened before the first instant, a hundredth of a second, of start-up; what is the character of the inside structure of protons and other short lived particles, are they made up of point particles that were only involved at universal start-up or in very active kinetic energy collisions?
Chapter Twenty-five - The Nature of Matter-Energy

In this we reach the bottom line in physical theory. What is the nature of matter and energy and what does their conversion mean. We intend to defend an original idea of Einstein's which he used to cover his ignorance of a theory of matter, a task that he devoted most of the final years of his life, what is called the search for a unified field theory. His original idea, as far as general relativity was concerned (note that that theory was formulated in 1918) was that matter comprised point singularities. We would like to agree with him; we would like to concede that leptons and quarks are indeed the mass point singularities of matter that all physical theory require (as matter, not necessarily as points).

But there is another piece of pure physics. It is called electro-magnetic field physics in vacuum (fields free of matter). That is the kind of physics that relates to light, and radio waves, and microwaves, and infrared light and ultraviolet light, and photons. These are waves, a combination of traveling electrical and magnetic fields of different frequencies or wavelengths. They all have the same speed, the speed of light, a constant throughout the universe, wherever you measure it. That speed is 186,000 miles per second (or 30 billion cm/sec. If you are practicing metric conversions, it is 300 million meters per second, or 300,000 km per second).

The electromagnetic field theory is 'perfect' if you do not ask where the waves come from, or if you do not ask too insistently what the waves really consist of. Oh yes, Einstein showed that they come in packets, of a finite slug of energy related to its wavelength. The energy of such a slug, that which makes up a photon, is proportional to the frequency. The constant of proportionality (remember the definition of action as the product of energy and time) is the quantum action for radiation. It is called Planck's constant. It said that the energy-period product of an electromagnetic wave is quantized, chunked. Einstein showed this in the photoelectric effect. Each time electrons flow in an electric circuit in which a suitable surface receiver of light exists, the number of electrons that flow and make up the electric current is proportional to the light intensity, a measure of the number of photons hitting the surface, down to where the number of photons can be counted as very small numbers. It is also related to the phonon theory of solids shown at low temperature. The low temperature specific heat, described as the type of cooperative sharing that takes place in lattice vibrations, is related to how the atoms emit and absorb radiation quanta. In fact, the basic rule, known as the uncertainty principle, stems from this quantization of electromagnetic radiation. We should first state that even if we did not fully identify the process, the photon is the exchange element which is emitted and absorbed by matter. Thus any mechanical process, involving as it must matter, will always exhibit a unit of elementary action (energy time) equal to or greater than the unit quantum, Planck's constant. Why? Because any such unit of action must involve at least one or more photons. Why? Because any interactive movement, if it is to be detected, has to communicate by photon exchange. Why? Because there is no other way to exchange.

The general doctrine which becomes quantum mechanics Einstein never wished to accept, even though he was one of the creators of the quantum theory of light (at least of its quantized nature). We would hope that we might have furnished an idea that he might have accepted, we have put it in here in our very simplistic way of expressing or 'demonstrating' Heisenberg's uncertainty principle.

What we are saying, in essence, is that there is only a pure physics of the electromagnetic theory in vacuum, and of the mechanics of point matter. The problem we have is what happens in the interaction between matter and radiation. First, we are saying that there is no real interaction between matter and matter. That interaction is always conducted by an intermediate,
such as a photon exchange element. That notion is perfectly satisfactory to quantum mechanics. But we are saying that the interaction, at the boundary of point particle matter, is not in this world, but attached to that which we call the nothingness of the vacuum, but which Dirac had had to prescribe with the notion of being a negative ocean. Why? We will see. Suppose we hit a point particle with a photon. Momentum is conserved (Einstein gave the photon a moving electromagnetic mass, even though it has no real mass. The formula is simple enough to work out, but we promised no mathematics). So either the particle bounces away and the photon is deflected, or it is absorbed. But suppose the photon is highly energetic, a very high frequency photon (an X-ray, or so-called gamma ray)? Then, quite remarkably, the particle - if quite heavy - may move very little, and instead two particles spring forth, a particle and its antiparticle. In the original descriptive notions, out of a negative ocean of cancelled matter-antimatter, a particle and a hole (its antiparticle) spring out. The antiparticle has opposite properties, a 'negative' mass as far as force effects are concerned. All the conservations are preserved - energy, momentum, mass-energy. That is how the notion of the negative ocean, or the busy vacuum, come into being. This is called pair production.

The converse process also exists. Smash a particle and its anti-particle together, and a high energy photon springs out with the matter-antimatter pair disappearing. The conservations are preserved.

Note that the conservations go very deep.

But we do not usually have point particles except for the leptons. Quarks are considered tied up in triplets (e.g., two ups and a down, etc.) Nevertheless the processes still work for these particles (e.g., proton-antiproton pairs, these are called hadrons, the heavy quark combinations).

To simplify the mysteries of interactions (not to explain the specialized character of the quark binding), we postulate that in all cases the interactions between matter and radiation take place at the boundary layer of point matter - whether the 'collision' process between photon and particle is 'elastic' (perfect conservation of the magnitude of momentum exchange but with a reversal in sign of the central directed component - that is, they bounce off each other), 'inelastic' (that is energy is transferred excessively to one or the other), or pair-producing. This model may be quite speculative, or colleagues may likely say that we have sprung it on the unwary, and those incapable of judging or evaluating its validity, but we suggest that it supplies the picture of what is happening at the very base. Regard it as a metaphor if you must, a shorthand for the origin of dissipation. Perhaps you can be better satisfied with the current formal abstract model. (We can't. For the fact is that radiation exhibits dissipation. Fill a cavity with electromagnetic radiation, and it loses energy in proportion to the energy density of photons in the cavity. The only cavity of pure radiation that is lossless is that whole universe. And the reason that it can do it, we suggest, is that it is expanding as fast as the loss. None of the other pure radiation fields would hang together, unless their momentum is confined by a matter shell. (Each photon is independent of other photons; in a pure electromagnetic field there is no interaction.)

So we have perhaps confused you in this chapter. We have tried to give you a very small, but honest look at the bottom 'mysteries' of physics. Our view is one 'mystical' view. You may like other more standard physical views better. But in any case here lies something or the character of ultimate mysteries in physics - where does matter come from, where does radiation come from? When both are present, we know how they support each other. If you want to, go back to Weinberg.
Chapter Twenty-six - Atoms - Ions – Molecules

Many would consider it peculiar to have talked about fundamental particles and nuclei, and matter-radiation interaction before talking about atoms - ions - molecules. The trouble is that it does not leave the reader with an idea of the atom's atomisms; this was the real problem that bothered Aristotle. So we swept that problem away by trying to get down to the very bottom, just as we looked at every other ensemble from the point of view of its atomisms.

So we know that there exist persistent entities known as nuclei made up of protons and neutrons (we didn't bother explaining what bound form in the nucleus, but we can now say that there was an exchange entity always in process, making up what is called the strong nuclear force. The process is consistent with the lepton-quark construct. Perhaps it is better to say that the unit grouping in the nucleus is the alpha particle, a helium nucleus pair of two protons and two electrons, which makes up the fundamental stable bound unit pairing - so it isn't quite simple boy-girl pairs). Also there are persistent electrons. Since the nuclei are positive (protons are positive, neutrons are neutral - charge is conserved in interactions), they can form bonding pairs with electrons.

Let us start with the simplest nucleus, the hydrogen nucleus of one proton. Why doesn't an electron simply clump together with the proton and stick, neutralizing the pair, say, or perhaps forming a neutron? The proton has a repulsing 'wall' very close, so apparently the electron could only revolve or hover, at most, unless it were shot very precipitously through the wall (a process that can take place). But why then, ordinarily, don't they stick? That begins one of the mysterious questions that led to quantum mechanics as an addition to Newtonian mechanics, or Einstein's modified relativistic mechanics. Another question. If the electron forms a revolving orbit around the proton (like the earth around the sun due to another attractive force, gravity), since it is an accelerating electric charge, acting like it is vibrating in two directions, why doesn't that electron radiate an electromagnetic field, lose its kinetic energy, and spiral into the proton like a sky lab losing its energy by dissipating it in viscosity diffusion by dragging through the atmosphere? Again the answer is quantum mechanics.

Had we not prepared a kind of classical base, we now would have to go through one of those tedious, earnest, gee-whiz, or dogmatic explanations of quantum mechanics, in the end winding up with "Because that is the way it is.” But we have already lowered the level of mystery. So we will 'explain' it in our terms. The interaction process only goes by radiation interaction. Put these pairs in a cavity containing radiation (originating from a wall temperature). They will absorb and emit radiation (as explained by Einstein). These absorptions and emissions will be by quantized photon exchanges. If we have a large ensemble of protons and electrons, they will gradually sort each other out into boy-girl (proton-electron) orbital pairs. At any time there will be some free protons and electrons. Those are ions - electrically nonneutral entities.

What happens with just one electron and proton? We will prefer not saying. It is a very detailed physics problem, but really of the same sort. It is the speed of the process of finding pairs that would be involved in the modeling.

That is fine. That says for each temperature there is a range of quantized orbits, hydrogen atom orbits, which depend on the absorption and emission of radiation of energy in the orbit. The orbits themselves, as deBroglie argued, are quantized in angular momentum because those are the electromagnetic frequencies that can form a complete ring around the solar system orbit. These would be stationary, unradiating, except in jumps. The jumps would resemble jumps between quantized orbits.
But why an orbit at zero temperature, the so-called zero point orbit? That is harder to explain classically. Yet Boyer has suggested a way. There is a background of electromagnetic radiation, call it if you will an electrical background of the big bang, which is not thermalized (Boyer has shown the possibility of such a solution for the electromagnetic equations). He calls that field a random electrodynamical field. That field, he has shown, can support the zero point energy. True? No, still very speculative, but a very interesting and pretty good speculation. If your favorite physicist does not like that answer, tell him to convince you of the total modern construct of quantum mechanics. Remember, however poorly he could fight them off, Einstein never accepted the pure quantum mechanical explanation which Bohr, Heisenberg, and Schrodinger tried to force on him. Chacun a son gout!

In any case, you get an idea of the quantum rules (we only argue as to the parsimonious foundation for such 'laws'). They leave one with a possible set of quantized orbits for all of the orbital electrons. For example, an atom of oxygen has eight electrons in orbit around a neutral oxygen atom, or few (or greater) for a nonneutral oxygen ion. The results of quantum rules make up the solar system-like structure of orbital electrons around nuclei. Thus there are a number of additional conservation rules for such systems. Mass, momentum, energy, charge are conserved (there is negligible mass defect for electronic binding). In addition, electrons pair up with a property that is referred to as their spin. When two electrons are bonded into the same system, if they have the same orbital parameters, they differ in spin. That rule, Pauli's exclusion principle, forms 'shell' orbits for electrons. They develop by such rules as two (for a first shell), eight (for a second shell), and further on. The point to these remarks is not to conduct a course in atomic physics, but to hint at a next level of interaction. Electrons are far removed from the compact nuclei. Thus when two atoms interact by collision, their far removed electron shells intercouple in orbits. Thus there are electrodynamically stable configurations more stable than isolated independent electrically neutral atoms. They bond and form molecules, associations of two or more nuclei. The simplest example are two hydrogen atoms, or even more simple a hydrogen atom (one proton - one electron) and a hydrogen ion (one proton). We ask how can one electron bind two protons?

As we mentioned earlier, there is a dynamic stable configuration, in which the electron orbits both nuclei. That bond is known as an exchange bond. It and the electrostatic bond are the major bonds that make molecules. And that, as we indicated, can be found in a gaseous, liquid, or solid state. These are three pure phases (simple phases) of condensed matter. There are many more complex phases.
Chapter Twenty-seven - Why Art?

There are likely still many puzzling problems regarding organized activities out there that still perplex you. We did not contract to try to cover every single one. But, in talking to reviewers, it was clear that there were some organized efforts that people engaged in that required some sort of explanation.

Clearly, art as abstract representation only arose with modern Man 40,000 years ago. Examine any book that shows such middle Paleolithic representations. On the other hand, artifact, tool, as abstract representation (artisan activities) arose with Man's very early hominid ancestors. (Written speech, as a very densely organized abstract representation, only arose with trading civilizations). So one may infer that art is related to the action modes associated with the modern brain, the neocortex and its particular association centers for 'language,' as a rapid exchange system by abstractions.

Art, in some sense, is an added abstract representation out there of what is inside. It can relate to any of the senses, and it may take on many representational forms. But why art?

We first ask the question - why science (or why sports)? Science, we have to define as the condensation, in representational symbols, of a large amount of phenomena by a parsimonious mapping or representation, one-to-one, of the phenomena out there and in the symbols. Science is at first recognitory (from sensing to perceiving, to cognition, to recognition), then clerical in its parsimony. This is all prescience. Science begins at the level at which it can describe the game out there parsimoniously, so that the description stands for the game each time you watch it. Science then explains what it is and why the players do what they are doing. Finally, science represents the entire game abstractly, analytically, predictively.

Why? Because, as Aristotle said, men have a need to know. It stills their fears and anxieties. They know what they may have to face. (It still doesn't help them avoid all fearsome results, but it helps to avoid some. It separates inevitable, from the probable, from the uncertain, from the unavoidable.)

In similar spirit, we detect that the human brain has enlarged the scope of branching paths more liberally than are needed for 'simple' survival. These included in the action modes, as part of the strategy of behavior, e.g., the animal (human) 'explains,' 'plans,' 'thinks,' 'attends.' Art, basically, represents the totality of created patterns which attract human attention to other than the fundamental needs. Art is a major activity that provides focus for the spare command-control capacity of the human brain. There is little evidence that other animals have such large organized complexes within their brains. (Although one can watch household animals 'attracted' to apparently human art forms, such as music.)

Strategically, those organized complexes of attention become part of the action modes (play, sports, science are other such complexes). Great art is measured by the number of people and the amount and number of times that successive generations are attracted to the representations. The science of art, esthetics, is the rules and methodologies by which the artist may achieve such attention, but again we are not writing a "How to" book. Many of the elements used are similar to those in science, but the difference is commonly in the final goal. The scientist tries to create an end object out of common elements which is general. The end object 'explains' a great deal. The artist tries to create one which is unique, the work of art. By its unique properties, the end object 'attracts' a great deal of enduring attention (instantaneous attention, e.g., startle, is not enduring attention).
Chapter Twenty-eight - Why Sex?

We have made clear what sex is for. It is to reproduce the species. As such there is an elaborate internal machinery within the organismic factory to assure the result. It is a mode that is expressed with great regularity. But note the problem. The reproduction slot for the female loosely is the menstrual range, perhaps 13 to 55; or the safer reproduction range is perhaps 15 to 35 (a range in which 20 births, statistically tops, can be achieved). The life span is 90 years. What happens between 35 and '90'? Of course what actually happens is that the life expectancy intervenes. In Paleolithic times and Neolithic times life expectancy was of the order of 30 or under. Life in the 'wild' is always quite regulatory of reproduction rate, mostly by child mortality. So it was with early Man. (It is now and has always been so within impoverished societies.)

But with urban settlements and farming, a new need for regulation of family size began. People, wherever and whenever 'natural' childbirth did not severely limit life expectancy, began to 'considerably' regulate the size of families. Social custom and religion sometimes reacted one way to offer rules for interference or noninterference, or the other way. Contraception, for example, can be traced back with certainty to the 14th Century to social groups other than prostitutes. (Prostitutes have always had various practices.) A good 500-year picture of outlook in one country can be found in Stone's The Family in Sex and Marriage in England, 1500-1800.

As is well known, while the Victorian Age, around the turn of the century, encouraged large families, discouraged any talk of sex or its regulation, nevertheless, both upper class society and lower class society indulged in their practices under their particular ceremonious epigenetic codes. Families now, in most industrial nations, have shrunken, at the same time that life expectancy has shot up to 70. Humans get closer to being one horse shays. They are born, they live out much more nearly to the human life span, then fall apart all at once. That 'squaring' out of mortality is only a most recent 20th Century, result.

Meanwhile there are the time delayed epigenetic memories - in outmoded religious and other social moralities.

What could you expect to happen? It did. There had to be a sexual revolution, a change in perception of how to deal with a deeply ingrained modality, sex, whose purpose was no longer procreation. Many ages have had to face changing needs and, after a time delay, they do. So why not ours? The revolution in the needs for farming families had already taken place by World War II. So the sexual revolution of the 60's took place, triggered in part by the new explosion in contraceptive means. (Did it depend on that trigger? No.)

So sex, or the perception of sex as it is out in the public consciousness, is the problem of dealing with the sexual mode, in the very young, premarriage, extramarriage, in the long period after the reproductive slot is filled. Instead of the more ancient ways of bodily exhaustion, child slaughter, war, disease, prostitution, unsafe abortion, we substituted tube ligation (in male or female), chemical pills, safe abortion, free sex, as well as the usual plain and fancy range of sexual practices of avoidance. Clearly one form of sexual practice or another will take place, or its consequences will be dealt with. In lieu of the fact that the organism cannot be quickly changed biologically, the individual will deal with the problem, and at most society can sanction the modes. We find no difficulties in outlining the course of a prudent individual and society, but you can choose your own. (Moderation, fit the physiological facts.) Once again you do not need our "How to" advice.
Chapter Twenty-nine - Why Religion?

We have been advised to tread carefully. So we will. Again appealing to the character of the human brain we have indicated that the notion of why things work is an ancient one, going back to Man's origin. That is when the first evidences of magico-religion is found. We have outlined the progression of steps - spirits, gods, God, with many variations. These are mystical because they cannot be found by all as 'cause;' they have to be accepted as faith by individual cognitions.

As Man began to ask questions about such matters, efforts were made, as the themes of the Enlightenment began to evolve (Man beginning to recognize and perhaps act in control of the forces of nature, in control of his own destiny, in making progress), to find logical proofs for the existence of God. Thus the variety of Thomistic arguments (e.g., how can there be a watch without a watchmaker?). That view was then superceded as a more 'scientific' view, by Newton's. Newton's was the religious noninterventionist view of a God who provided principles of operation and material, and a start. After that the system runs itself. The subsequent scientific views were the pantheistic 'believer-heresies' of a Spinoza or an Einstein of a general spirit, in fact the laws of nature (or of physics) themselves which permeated all matter - energy - extension.

The 'faithful,' in many religions, accept the first Thomistic view, or the more primitive view of spirits. The scientifically tolerant, but loosely religious, accept the Newtonian view. Those who really have little religious view, but share a widespread mystical view of some basic commonality, adopt the third outlook.

Then there are the skeptics who have no sense of deep commonality. They perhaps have Bohr's outlook of a considerably disconnected body of random events. That may not be precisely their view, but it is hard to discover what general order they put on all of creation.

So you can see that you are faced, by the character of your brain, to adopt some strategy of explanation of how, what, where, or why the rule of motion and change (the laws of physics) come from, including denying or adding one or more aspects of such questions. We are certainly not going to tell you “How to believe.”
Chapter Thirty - Why Do We Grow Old?

Because parts wear out, processes become mismatched - memories similarly get rusty, muddled, or lost. Where? In one or more parts of the body. The issue is not settled. Some believe that one or the other body systems leads to the decay (we hold for the gonadal system; some believe that the cardiovascular system lead the parade). Other believe it is a cellular process of mismatch, but what cellular process decays is not perfectly clear. One kind become of story is that cells can only divide and grow up so many times before they mismatched, and that this may be a key process in particular organs or regions, or cell types in the body. A good answer to your question? No, not yet.
Chapter Thirty-one - A Summary of What We Have Learned

Suppose we ask the question: is there a general set of principles that could explain how complex systems work? How can we discover those principles, in most economical form?

So we start with a mental picture, for example imagine a circle (or a sphere). This will represent the 'stage' of the system (the actual shape of the stage of the system can be considerably different - this is just a representation of the extent of the system). What is in the circle? It is the atomistic or isolated system of concern. Perhaps it is a representation of cosmos, or a galaxy, or a star, or the earth, or a person, or a cell, or a molecule. That puts a picture of the whole player on the stage.

Now we can imagine what the system looks like at different times. We can imagine taking pictures of the stage of its life.

Systems have a spatial stage (or domain) and a time frame of behavior.

We look inside the space-time frame, and in addition to the gross system morphology (form), we find that it is made up of atomisms - many similar entities that have their own walls which are engaged in active processes, and which preserve their identity even with motion.

Our atomistic (bounded) system itself is made up of atomisms.

What happens in a system?

In the interior of a system, the atomisms change their states, but if the system persists, they run through a cycle of states.

Why? Because they cannot all be in the same place at the same time, and because systems have energy. We have a choice: either systems have energy, or they have spirits (e.g., soul, spirit, gods, or other names or measures of universal or local actuation). Philosophies branch here. We elect the quantitative, 'objective,' measurable predictive, communicable, instrumental, unique path that we ascribe to western science. The reader can choose otherwise. He gives up these characteristics. He cannot come back at us and say there is no predictability out there (or out there does not exist). All he can say, and hold to, for example, is that he assumes no predictability and there is no way we can dispute with him. Those who have not made up their mind (i.e., decided on what patterned abstract construct they use as a strategy within their brain space), may ask us or those with opposing views for evidence and draw their own conclusion. Hopefully, perhaps we can convince him that these perceptions of cosmos, galaxy, star, planet, society, life, Man, cell, molecule, nucleus, fundamental particle, negative ocean are real and can be indefinitely correlated in space and time, the essence of prediction. We do know, as an experimental fact, which mayor may not carry weight with all, that a knowledge of the order of events in the heavens were helpful and necessary for Man to become agriculturist. That may have imposed the space-time-action tyranny of climate and the soil. But before, that, man was tied with a similar tyranny as hunter-gatherer. The process of life requires - for most of us - knowledge of such causal sequences. Our lives depend on it. The anorexic child who believes it is not necessary to eat, becomes quite ethereal and dies. End of that conversation.

Atomisms move under the action of energy transportation and transformation. The only kinds of break in motion, we can identify abstractly, is elastic collision (bounce a stone against a stone), fluid drag (watch a stone drop in water, or watch a leaf drop in air), make, break or exchange parts (crack open a stone, stick two leaves together with water, or watch animals mate), or delay and absorb motion into the interior (build a dam of tree logs and watch the water in the pond rise, wound an animal and watch it die)

All of these actions and reactions can be attributed to spirits or to physical processes. They arise, in either case, out there - not within your mind - and they are mapped within your
perception space. Their reality, independent of you, is attested by the fact that you, the cat, the blade of grass, and the stone all show 'causal' signs of connection when the stone falls and is 'sensed' by all. That is the doctrine, or dogma of science. And it proceeds from that doctrine. So instead of spirits, we deal with forces that can change motion, and in time we succeed in identifying the forces and the fact that they are very few.

In answer to the Greek speculations of whether materials out there that there are one, or few, or many, in time we succeed in identifying the fact that there are very few.

Aristotle decided that atoms could not exist because it would lead to an infinite regression (form within form within form, indefinitely). We have turned the argument around and showed many such levels but not indefinitely many. Starting from ancient explorations, by examining the materials of everyday usage, within the past few hundred years we began to establish a sense of ‘the’ atom, a limited number of basic entities, the elements, which made up all of matter around us. That turned out to be about a hundred. All materials around us can be broken down to those constituents.

“Yes but - " voices the cry, "You have so destroyed the essence of the system, that which made the system viable (or live, or gave it its emergent properties)." That is true. So we have started the more difficult physical task of synthesis, of putting the pieces together and showing that we can build up those systems. That has required learning a great more detail about the forces, the arrangements, and the sequencing of processes. That has forced us, as physical scientists, to become engineering-physicists, ones willing to deal with both simple and complex systems.

A complex system, internally is a factory. It exhibits all the kinds of breaks in motion that are possible - elastic, fluid-like, exchange, delay. It sequences them into cycles. That is the only way that systems can persist for a lifetime.

But in addition, if true, then systems have to be assembled (start-up), live a life time, and degrade.

The acceptance and 'proofs' of those propositions have to do with our capability for synthesis. We will illustrate:

We can take ore from the earth (or gas from the atmosphere, and liquid from the oceans) and separate it into atoms, in single units, or in bulk. We can combine them into making molecules, and create macroscopic forms. We can make steel buildings. We can make materials like wood. We can make fuels, for machines or for living systems. We can take many such elements and make an automatic factory complex. We can duplicate the processes that run the sun. All this is well known. So the issue is what we cannot do, what we cannot synthesize? The clear answer is those systems characteristics that seem to be possessed by life. There are also those processes which are scaled at such large sizes that we have difficulty in simulating them or absolutely demonstrating them on earth. But the perceptive will note that with very fine instrumentation, we have shown capability of demonstrating the beginnings of most of their effects at small scalings. So it is really the living systems problems that remain the sticking point. And rightly so, for it was the characteristics of such systems that were largely responsible for the notion of spirits (and souls, and self-consciousness, and freedom of choice). These problems relate to life, mind, society. Where do we stand in their synthesis?

The biochemistry of life, at the molecular biological level, is moving right along. Whether one approves or disapproves, nevertheless even genetic engineering is on the agenda. All of the molecular constituents of living systems can now be synthesized in the chemical laboratory by pure physical-chemical assembly processes from atomic constituents. The large
sized entities, protein molecules, now have their assembly maps appearing in many scientific publications. That 'easy' capability is almost less than ten years old, certainly less than twenty for its beginnings. In the past few years, the capability of 'building' parts of the very simple organisms (such as bacteria) from synthetic chemical (i.e., synthetic genetic material) process steps has developed. It is not yet possible to [We have finally, NR] synthetically build a full chromosomal complement that will give the instruction to build an entire simple organism, but it can be done in parts. Synthetic genes can be inserted in an existing complex (genetic engineering) and the form or function desired will be expressed. Emergent property from chemical synthetic assembly. The total assembly task for an organism is only a matter of time. Much of it is a matter of mastering and developing a large scale engineering methodology for the specific purpose. Someone will soon be rich enough and skilled enough to do it. The headlines will read "Living organism (including emergent form and function) has been synthesized!" (How much more definite do you want the prediction to be? Where will the headline be? In practically all papers, certainly the New York Times. When? Within the next ten years! Suppose we are wrong? Very well, the twenty years.)

Brain? We do not know how to build a brain. But this is a sore point with us. The reason no one knows how to build a brain is because the totality of function is very complex. The mechanism has had a long time to evolve. But - we have offered, for the past ten years to build a mechanistic system capable of doing the major thing that a living system can do, which is survive in the field for a lifetime. Believe it or not, we have had no takers. The problem we addressed is not to demonstrate how life does it, but to demonstrate the physical principles that are sufficient to support a life-like system.

On the other hand, the synthesized cell (when it happens) will already show the basic characters of a command-control system that makes up brain-like function. Thus the synthetic problem is really more like showing a capability of taking a multicellular organism, say removing its nervous system (this is obviously at the level of organisms with very simple nervous systems), and showing that a new nervous system can be synthesized and put in to replace the old. Or there are various part way stunts that will be done. Lift a brain from one complex organism, run it outside for a long period; put a brain from one animal into another. These are all only steps along the way to making certain that the major wiring diagrams are understood before all of the details of synthesis (even of simpler organisms).

As far as synthesizing societies, we do it all the time, in part, whether we do or do not build all the parts from scratch. As we have indicated in our various social applications, one assembles ingredients, and one generally acts at the command-control cycling escapement, the ruler, for the process. A few illustrations:

One assembles some roosters and hens and creates a chicken-egg factory.
One puts together some people and puts together a company.
One puts together some seed and ground and creates a farm.
One (not us, some rulers) ride in, take over a settlement, and become the ruler.

The basic principle in running complex systems is to know how to balance the fundamental conservations - materials, energies, action modes, population - and to know how to do it from the available potentials.

We have often stated in engineering circles that most systems (engineering systems) are not truly systems (complete with their command-control system) until they are completed by the human as a command-control system. But then we are willing to show that it is possible to develop real
systems (that is synthesize them) without a human command-control. That is the point of the autonomous system we offered to build.

But let us turn back to the examples we have cited. Would it be impossible to start off the chicken-egg system (confined or isolated in its stage), or the floral system, or the social system without you as ruler, to where it will persist and run for a lifetime? Isn't that what civilizations do, without you, even if your name is Cyrus, or Ramses, or Alexander, or Washington? The more specific question is can we organize a segment of social ecology wherein it runs the same with you as escapement as without you, for its lifetime? Solving that problem, we believe, is the equivalent of much of the required synthetic task. Perhaps many people do not feel up to the task. We do. So think about that.
Chapter Thirty-two - Message from the Authors

Hopefully, you now have an idea of how things work. At least, we have given you a list of basic principles that govern how things work. We didn't cover the home plumbing, and the dishwasher, and how to make a million in the stock market. But that wasn't our intent. Our principles (e.g., basic physics) cover such problems too, but there are more technical "How to..." books (both engineering and layman books) for such matters. We have given you the principles and philosophy.

So what? What can you do with it? Our intent is to tell you what you can do with such a scientific construct rather than with the construct of any mystical, or religious outlook. We assert that our scientific foundation is required if you want to know how to run cities and nations, how to run yourself, how to feed people, how to help people give their children a happy future, how to have the energy to run a big country.

First, our science can tell you what you cannot do with our construct, or what you cannot do easily. You cannot influence the cosmos, or a galaxy, or even a sun. As an individual atomism, you cannot influence the planet earth, although the ensemble making up the human species, of which you are a member, can now begin to influence the surface of the earth and systems on it. Of course that ensemble influence can also affect you. So this is the first level in which what you do might have some influence.

You have a little more influence in your polity, that is your country, perhaps a little bit more in your own local community, and certainly in your immediate family, you are a big 'wheel,' a major member of the constellation. When it comes to you yourself, you are the major influence in the governing of your own organism. Below that level, your influence begins to fade again. You have some control over your organs (convince your heart not to fail), a limited control over the atoms and molecules that make you up, even less over those that make up the atmosphere. You can walk your atomic nuclei around, and your leptons and quarks, but they hardly sense your constraints on them.

So that gives you some picture of where you stand, what you are tied to meaningfully in reciprocal fashion, you to them, them to you. What do you want to do with that information, what can you do with that information?

As we explained, the geneticist measures 'success' of a species by survival and survivorship. Physically, as a criterion for systems' operation, we too can only choose the 'goal' or 'measure' of survivorship. This appears to be the only rational basis for morality. If you as an individual want to kill yourself, you don't need any special instruction from science. The same is true for your species. All systems, we said, are born, live, die. You have some 'controllable' ties to the life of yourself, your family, your species. When we move beyond that level, e.g., to other species, to the atoms and molecules that make up you, these levels seem to have little 'personal care' for your concerns, although they too are likely 'concerned' with their survival (as systems). In an objective sense that is all there seems to be, birth, the regulation of a life span, death. Your parts assemble, they persist for your lifetime, they come apart. Along the way, your constituents may turn over.

So, if you wish to define a 'goal' or 'purpose' in conducting whatever stewardship you can, serving whatever function you may, it is these principles that can furnish the only consistent principle of command-control. We offer you this as the only objective basis for morality: Assist in the regulation of the life span and life characteristics of those systems' levels over which you have some control. Note that you are only a passive participant in the characteristics of all other systems's levels.
This does not mean that you are not 'in tune' with all levels, but you cannot usefully reach all levels. They may have some authority over you; but you cannot touch them meaningfully by your actions.

Also note that while the foundation of belief, physical reality, is different from the mystical or religious beliefs, nevertheless it arrives at a possible foundation for action, a morality, which is not remarkably different from other belief structures. (Only it does not start from morality. It starts from the reality of existence.) Understand the basic functions and 'purposes' shared in reciprocal fashion. (Translate this as sharing at least empathy- love? respect? - with your neighbor.) Also it takes on only the limited 'cosmic' role - try to understand 'everything' if you will, try to be in tune with universal processes, but the proper concern of Man is Man, because that concern is all we can influence. So what does such a belief structure do for us?

For any Viable System. If such a system 'understands' and can communicate within itself and among its other ensemble members, then it may learn that survival is the only appropriate goal. (In a pack, does the leader defend the pack's interests, or the leader's interests?) That immediately poses the dual problem - survival for the individual, survival for the ensemble? An economy of effort suggests that one try to optimize both, but that principle may not be compelling to all individuals. One senses that the extreme is to optimize one's own existence and offer a little amount of effort for the species ensemble's persistence. We can say no more because this proposal is both the 'is' and 'ought' of individual conduct. In viable systems, their viability (birth in a womb or other workshop, and their ejection into a world of external environment in which autonomous functioning is required) depends on their achieving and satisfying their essential conservations. In most systems, the action spectrum that assures viability is stimulus bound. The conservations come off from such routine actions. That is why the system survives. (You don't have to make a special effort to breathe to get oxygen. The body machinery functions to do it for you.) But it is the usual case that the space and time scale for the individual is much more compact than for the ensemble. Thus the action space of the individual, by its basic topology, has to be more crowded with his concerns than the concerns of the society. When we come to sentient or sapient systems (we will have to regard essentially all systems as sentient – they do have to 'sense' in order to exist), particularly sapient systems that can internally control their short term 'wills' or 'won'ts,' the basic division of activity and effort cannot really be different. So a harmony with physical reality still is the only tenable guide principle.

For the Human Individual. You know your life span. It is true that most people, or particularly the young, think and act as if life had no end. But it does. In any historical epoch, one senses what that extent may be. We now have a rather specific idea of the life span. It is about 90 years. (Extremes up to 114 have been reported.) But this is different from the life expectancy. Up to Neolithic times, perhaps 8,000 years ago, the life expectancy was only 20 years (even though the life span was still 90). It was still long enough to get a replacement population born, with very very slow growth. Up to a few hundred years ago, the life expectancy was only 30 years. You still could not afford to hold any very strong feelings toward any children you might produce. Life expectancies of 50, 60, 70 years are only the product of this century. It is only 'now,' that you can have children young, say under the age of 25, help them grow up for perhaps 20 years or so, and then have a 'free' life, one in which you can 'freely' enjoy yourself, for another 20-30 years. Can we get such a prospectus across to a 15 year old, or a 25 year old, 35 year old, 45 year 55 year old, 65 year old? We don't know. It is very difficult.
Yet we will try. We will imagine we are speaking to a 15 year old adolescent. The 'maximum' opportunity for some sort of planning is possible then. If that adolescent has been seriously deprived - of cultural, emotional, educational, economic opportunity - it may be very difficult to make any useful intellectual impact. It is neither their fault, nor ours. The support ecology offered by society has simply deprived them of communicational ability and epigenetic stores.

One can become economically rich, or economically poor. If you become economically rich, many people work to provide support for your mode of living. Is the option open to everyone? No. However in all sorts of societies, it is possible to try to work toward economic richness. Do many succeed? No. The possibility is only open to a few percent of the total populace, and usually most openings are already spoken for by a class that is already rich by inheritance. (Their family owns wealth, or controls social position.) We are not writing a handbook on how to become rich or the morality of being rich or poor, so you must seek such answers elsewhere. To become economically poor, requires no special training. Again, since there are more poor than rich, e.g., perhaps 15 to 35% of a population is poor, your chances are much better to become poor, and in addition, a lot more people already have a hereditary grip on that type of life.

So you see that you must make some considerable effort to find your social niche. Of course your parents have generally given you a goal model or a role model on what may be open to you, and in most societies, society has also conspired to give you some sort of picture. Are you absolutely bound by any of these pictures? No. But it takes considerable effort, in any case, to reach your niche.

The same kind of analytic remarks can be made with regard to all of the other conservations - of material possessions, of available energetics, of the matrix of action modes, of the population numbers, of the value-in-exchange (money or credit) that you are involved with. The role you seek has two sorts of limitations: one the external limitations, the state of the potentials in the region you live in or can emigrate to - these are the climatic, the geographic-ecological stores, to a limited extent your own onboard genetic potential, the state of technological advances, and the onboard epigenetic potential you have acquired; the second, a product of the genetic and epigenetic heritage within you, your working outlook of the world out there. What do you want? To be the richest person in the world, the greatest athlete, or entertainer, or lover, or leader or gourmet? Each one of the superlative states you chose is beset by certain astronomical odds. As an individual you are playing in a 'crap game,' or 'card game,' in which you have to play with what has been given you. There are obvious ways to increase the odds. There are obvious safe plays, etc.

So all we can tell you, in a general way, what may more or less work better than other choices for most people. There will always be a few who will be special or lucky winners. But, as usual, we must start with the injunction, "Practice, attend to your affairs!" (Tend your garden!!)

So we set forth the usual prescription - what is required for a long and happy life? The answers, still, today, come out to be the path of moderation. As best we know, a long and happy life is based on a life of moderate and enjoyable work, a moderate diet with considerable activity, few destructive vices, a somewhat disengaged or relaxed view of life's activities rather than a hyperactive driving compulsiveness, a good empathetic relationship with a mate. Can you control all of your actions? No. Consider how difficult each of these tasks may be for you, for others? Can you give up smoking, adopt a lifelong form of moderate dieting, stop getting angry, control your impulsive desires, moderate your hatreds? When a moderate kind of life succeeds, it
is not necessarily at any extreme end of success (or failure). The prescription offers no value judgment; it is not the case that an extreme intellectual, or moral, or public, or wealthy life is better than any other. However, we cannot gainsay anyone their privileged choice. Dull? That is in the eyes of the beholder. If you want to try to drive for the top (or bottom), then choose what you like, but remember you may have to like it for a lifetime!

For the Social Ensemble. The choice of a moderate life that fits the needs of the social ensemble is obviously a good one. The same principles by which one satisfies one's own internal conservations, as basic needs, work once again to satisfy the social needs for survival. But as we said, you may select or 'elect' to serve society at its extremes.

Once again we face the need for a principle for regulation and control, here of the society. Once again, this really has to face the issue of where in its life expectancy is the society?

A comparative study of civilizations (or their small form of isolated cultures) show them to have life expectancies in the range 350-500 years. An observation of such regularities is old. It goes back at least to the Chinese philosopher - advisor Mencius who noted that Chinese civilizations lasted about 500 years. However, civilizational life forms do not have the fixity of biological living forms. Civilizations may be the reforming body of an older civilization, a reshuffling of existing forms of polities, or a settlement in a territory heretofore unoccupied by civilization (but already marked out by people). A reader seeking an introduction to civilizations, may find Darlington's The Evolution of Man in Society to be an excellent first overview of Man's history, or Melko's The Nature of Civilizations is useful for comparative typologies. A survey of all independent cultures that have been documented may be found in Murdock's Ethnographic Atlas.

What we find, if we study all of Man's history, by typologies, by following it as a serial story, by comparative ethological study of Man among his hominid ancestors, or Man among primate 'relatives,' is the existence of an elite leadership. In primitive hunter-gatherer days (most of Man's existence, e.g., 30,000 out of 40,000 years), there was hunter leadership of camps cooperatively linked into a band in a roaming area. With some social transformation in fixed agriculturally based settlements, or nomadic cultivation of domesticated herds, the elites of modern fixed trading societies emerged. With a new conservation, value-in-trade, and the convection of trade, stored wealth beyond anything that hunter-gatherer ancestors possessed become possible. With storage possible, in fixed settlements, of any of the basic conservations - materials, energy, action modes, population, value-in-trade - wealth and power over any or all of these conservations was possible. As Mosca (The Ruling Class) states: "In all societies - from societies that are very meagerly developed and have barely attained the dawning of civilization down to the most advanced and powerful societies - two classes of people appear, a class that rules and a class that is ruled." As we hinted, likely we can trace the basic reason for such a development within the brains of the human species, foreshadowed by hominid and primate ancestors.

Perhaps the particular elite leadership appeared because of an ability to integrate the task of hunting, or farming, or animal husbandry, or fishing, or band formation among the group, or of 'divining' the natural course of some events (e.g., local or seasonal weather). But with fixed settlement and trade, and a technological ability to exploit natural resources, the capability of creating stationary wealth erupted. Richness in 'urban' human settlements, from origins nearly 10,000 years ago, from Jericho to Catal Huyuk, on to dozens of settlements in the period 6,000 to 8,000 years ago, on to the emergence of the first well documented civilizations of Egyptian Kingdoms and Sumerian city-states is well documented.
Why does history become a history of these elite leaders, those who as kings, or priests, have marched in and seized power, or who have had power turned over to them by hereditary succession? Why are these elite leaders largely the creators of the forms of civil government (command-control of a nonroutine, not stimulus-bound nature, one that must be invented and imposed by mind as a set of 'arbitrary' rules) and their evolutionary succession?

This is as true 6,000 years ago, as 4,000, 2,000, pre-Marx, during Marx' life, and post-Marx. No prior political form of governing command-control, not 'new' forms of socialism, communism, or post-revolutionary outbursts, seem to change the outcome of social bonding formation. It is true for a species, the human species, which is said to be sapient, and possess 'free will'. Somehow, men cannot govern themselves by their own cooperative efforts, at least not for very long. They seem to need leadership as soon as the complexity of relationships seems to exceed a certain minimum.

This is said with the greatest of sadness, by authors in a nation which has been considered to be one of the great experiments in the history of political thought, the democratic republic of states of the United States. One may read political history, as written by the Greeks (e.g. Aristotle), as practiced - in a search for democracy - by northern Italian city-states in the Eleventh and Twelfth Century (see Skinner, The Foundations of Modern Political Thought, Vol. I), as written by founding fathers in the American constitution (read deTocqueville for an 1830 view, dwell on the American self-view in the first quarter of this century, and consider the future we now must face). One senses that the beacon light of a self-governed large populace in an industrial nation, capable of wisely governing its own future for the benefit of all the citizenry is once more receding out of reach.

Instead what do we find when we examine history? Wars every generation in the trading ecumene. Powerful new elites making their play generation by generation, serving their own needs. At the group size or above, people do not govern themselves.

So, where does the societal problem arise, and how does it impinge on the individual's capability to influence society?

Note the problem we had in defining an 'optimal' life form for the individual. It was a moderate life, a low duty cycle. In a biological sense, the biological mechanisms, e.g., the human's, is designed for low duty cycle. We can illustrate. Resting metabolic rates are about 1600 kcal/day for a male adult. Peak sustainable performances (sustainable for hours as in marathon races) can produce 25,000 kcal/day. Yet average metabolism is about 2500-3000 kcal/day, with sustained daily averages above 6000 kcal/day almost impossible. (One runner ran 167 miles in a 24 hour day, representing a level of about 10,000 kcal.) And so forth for other directions of challenge. There are generally large costs for extremes.

So how does a society, without the drive of its elites, work? Generally at the level of a common perception of 'easily' available technology, and moderate effort, within an 'easily' transmitted epigenetic heritage, given the climatic, geographic, and ecological conditions, people tend to exist in society with a modest amount of cooperation sufficient to get the task of living done. They tend to act as species domesticated by the existing system imposed on them from birth. The drive to move them beyond such low productivity limits come from the elite. What do the elite possess? Practically nothing in any excessive amount except, commonly, a hyperactive drive. They generally want something or things extra-monetary wealth, power, admiration, other forms of wealth. (One more 'force' that drives society, is the intellectual effort of earlier centuries that raises 'consciousness' centuries later. Our current image is affected by the 16th and 17th Century revolutions in thought that culminated in Newton, and in fact led
society to the American and French revolutions. Hopefully, efforts such as ours may raise consciousness a few centuries from now.)

Would it not be possible for people to band together cooperatively and rationally and objectively expend perhaps a fraction more than their ordinary expenditures for a common advancement? Yes, but it is not a stable form. They will not persist in it.

So these are the facts. What can you do to improve your lot in society by improving society's lot? We will give you the prescriptions. We have little belief that you can carry out the prescriptions. Like dieting, it may attract you for a moment - a day, a week, a month, a year. The sustained effort, all your life, transmitted generation to generation, is not there. Nevertheless we will tell you the prescriptions. They are not idealistic. Yet you cannot achieve the steps. They require more energy than you will put out. (You can't run 167 miles in a 24 hour day with any regularity.)

You must cooperatively agree on rules, given the potentials available to you (climate, geography-ecology, genetics, epigenetic heritage, technological state and rate of change), to work out balances in materials, actions, energetics, population, and value-in-trade that satisfy your individual needs, your family needs, your local community needs, and your national polity's needs. "Humanistic' ways are: 'socialistically' in common; 'cooperatively" by separate groups, or 'capitalistically' by the organizing capability of individual leader elites, each involved with separate groups. Stability seems to exclude the first two. Even when they are practiced, elite leadership takes over. So it would seem to us that the only real possible solution is a people clever enough to manipulate their leaders. The trouble is that, ultimately, in a sequence of leaders, one arises who is smart enough to grab onto and hold onto power. Power, it has been pointed out many times, corrupts. Actually, of course, the skill of an elite leader is to know how to manipulate a group. And so real stability seems to lie in a cycling through of various forms of leadership. It is some such cycling of the shape of authority and the ability of leaders to impose it and people to resist that seems to create the life form of a civilization.

Of course another aspect is that leaders arise who are not satisfied with a moderate role. So, commonly, there is an alternation of territorial aggression (or defense) and trading aggression. The fluidity of international relationships thereby ensues.

We do not have to elaborate on the many nonhumanistic ways of running societies and intersociety relationships. The history books, ancient and modern, are equally filled with those stories.

Do you see why you, as an individual, in a statistical sense, can do so little? You have to realistically concern yourself with your own organism, for the sake generally of your own health and viability with 'family' relationships, and both of these you can often barely cope with. Your capability to deal with your community affairs depends both on its organization and the amount of action modes you can energetically give up for the purpose. In systems designed cooperatively, the task is much easier. But to reach up to national levels takes a great deal of effort. The one who chooses to become a political official - elected or appointed - can do so, but he or she must devote an entire professional career to that end. It simply does not fit with ordinary life conduct.

So there you have it. Either accept as 'comfortably' fitting a life as you can, or - if you are highly energetic seek ways to 'beat' or 'control' the system. Only a small fraction succeed in the latter game.

All this may seem to be too bland. So we will give you one final set of 'answers.'
In a more rudimentary agricultural epoch (not so long ago, prior to 1925), the very local social machinery could be run by an individual's own choice. A family could afford land, and by hard effort, could farm. That age is over in the United States. As a highly industrialized nation, people have been forced to the cities and tied to the corporation, whether production or service. But in the end, society is still a machine for turning over the necessities from the ground and sky. This still requires minimally materials, energy, activity, population, and - since we elect it - value-in-trade to deal with flows between population centers. The potentials are still climatic, geography-ecology, genetic, epigenetic, and technological. However, that does not fix the political form of government. We still have a 'choice' of democracy, anarchy, fascism, feudalism, socialism, communism, dictatorship. In any case, we will still be saddled by elites. So what is our real choice? In any case, let us make our elite work for us. Let us come as close as we can to an equitable society. Let us insist and participate in some rational planning. We do not all have to immediately respond to signals of "fire, fire" and all run simultaneously for the exits. That creates disasters. Can we not elect more humane societies? If it be capitalism, let it be capitalism with a human face; or socialism. Do you really want or expect fast answers to all your major perplexing problems, right now out of this very elementary book of knowledge? There would be few believers. But if one can, lay down a prescription for running a moderate household, and practice it, one could similarly lay down a prescription for running a national polity, or a local urban polity on a moderate course. To do what? To solve such problems as:

- energy-material shortages
- inflation
- race relationships
- the large inequity between rich and poor
- the quality of life
- a program for the future
- improved health care
- reduction of the ravages of war

Will this eliminate war, disease, the differences between rich and poor, etc.? No. Rational objective planning can mitigate their deteriorating influences.

To indicate perhaps that we mean our story for real, we will offer very brief, perhaps cryptic outlines, of what it takes to solve some of our big problems. By putting down such answers, we may discredit ourselves in some people's eyes, but that is neither our intent, nor concern. If we suggest that we have no answers, then the reader may sense that our construct is not more useful than some religious or mystical view, e.g., God rules over all, and He decides. Instead we are proposing that, within limits, Man has some significant control of his own destiny.

But our 'rational' scientific proposals are only tossed out, in this document, for openers, to start discussion, not as a final word. So

The Materials-Energy Crisis, Steps Toward its Alleviation

2. Exploration for gas and oil resources.
3. Exploitation of coal - new processes. (Coal, the old fashioned way, is no solution. But largely coal expansion is for central electric supply. There are two directions that have to be explored - re-examination of the total industrial process, including transportation, for supply by
centralized power, or synthetic production of fuel for decentralized or mobile power. These are both costly conversions. Yet coal must be depended on as a major transition supply for the next number of generations.

4. Development of some nuclear energy. (The public, quite rightly has to be suspicious of significant risks to life. But nuclear energy with mild risk is conceivable, and it will have to carry a share of the energy-material burden, in forms similar to the present for the next few generations, and perhaps different afterward.)

5. Solar energy. (Current technologies will not reach out to making solar energy important. A great deal of research and development is needed for the next few generations. Our fossil fuel resources and conservation are supposed to give us the time to do the required work. That R and D hasn't yet begun significantly. It is still devoted to current states of the art.)

6. Other geophysical sources - wind, ocean, earth sources can make contributions, although small.

What is at issue is whether one supply (as gasoline and the internal combustion engine provided) can be the answer for the future. A dependence on largely renewable resources, with careful husbanding and turn over of nonrenewable resources may require a broad spectrum of answers. At least that is what we sense. What is optimal for the home may be different from that for transportation, or that for industry.

Inflation. One may sense that the American solution requires drying up a large fraction of the American dollars loose in the rest of the world. The problem wasn't created today, in the current oil crisis. It is aggravated by that crisis. Since the aftermath of World War II, the Marshall Plan and the entire world recovery, we have unleashed so many American dollars abroad, that our current problem is to dry up perhaps 100-200 billion dollars worth of those dollars. This cannot be done instantaneously, perhaps it may require 10-20 years. But it means that Americans can no longer buy foreign goods (automobiles, clothing, electronics, steel, luxuries) in unlimited quantities. Nor can Americans encourage corporations with mixed interests to take corporate advantage of American opportunities. If they are not working for American citizenry, they must be treated as foreigners.

Remember that a large part of that escape has been of American capital. They have used the American dollars to buy up a large amount of foreign national assets. How much? They now have as much money and value outside as the total industrial plant at the turn of the century. That is not a trivial amount. It was enough to take America into its strong superpower position by the middle of the century. That outside ownership does not do America any good, nor the nation that has been so bought out. No more does it do Americans any good when foreign interests come in and buy our resources out. This process is now taking place at a rapid pace.

We point out that the end of the process is an industrial serfdom for our American citizenry. Is there any difference in that 'absentee' ownership and control when America practiced it on so-called banana republics, or when it is practiced on its citizenry? Wake up Americans, before it is too late. You had better stop paying attention to the beguiling advertising and its payment by tax exempt grants, and start thinking very hard about your future. Many civilizations have come down when the people lost sight of their own long range interests and turned them over to foreign adventurers and adventure.

Race. Come off it. We, Americans, created and encouraged slavery when it had been dead allover the world for hundreds of years. And, at that, we only encouraged it in wholesale lots after the l820's. Fine, pay for it and get the issue over before it pulls us down. We suffered
it through the shaping of our nation, through a civil war, through a reconstruction, through most of the 20th century. Let us get rid of it, once and for all.

What does that mean? It means that every segment of American organization has to do its share - rich-poor, men-women, bankers-professions-trades, etc. Absorb the racial 'minority' and get on with it. That does not mean that the process hasn't been taking place, since the 1950's. But it means that the problem cannot be restricted to the poor. It must be spread throughout all of our society. The bigots have to be defused. The avenues have to be opened. A generation or two of wise-guyish, chip-on-the-shoulder response has to be expected and tolerated. An educational job has to be done on all. It is painful, only in the sense of all the adjustments that have to be made. But let us get them over with. Else you can have indefinite fester - as the Irish, French-Canadians, Israeli-Arab, Basques, etc., etc., etc., ethnic differences have shown.

Rich-poor differences. It would be nice if such inequities could be abolished. But it is simply not characteristic of the human species, not with fixed settlements, and trade, and value-in-trade. The net effect is that elites will arise, and they expect to be paid for their hyperactive efforts. Many people have to support them.

Why should we support them? Because they increase the total productivity. Thus if we have to devote a certain amount of our effort to support them, we get - in toto - a larger return. Where did it come from? From their efforts, e.g., investment, or organization of production, they increased the flow of potentials from the ground. If you do not want them, do it yourself!

But then you may see that their existence is conceptually value-free. Their existence is independent of the form of national economy or ideology.

What you can do, as the more common person, is to make them work for you. The elite's reward may be tempered. Note your current American position - you have encouraged the annual return of entertainer (including athlete) and other unessential action roles to be up to 60-100 times your average return, etc. This doesn't make sense. A top 2-4% essential elite structure, in a populace, that works hard to double national productivity is worth 10-20 times the average income of the populace. When measures go greatly beyond such limits, you know the society is off on unbalanced paths. The history of declining societies all tell related stories.

The difficult problem is that the perceptions of elites and what they can do differ in the early organizing phase of a civilization and the late deteriorating phase. In the early phase, what they do acts to build up the system; at the end they act to tear it down.

But all of these prescriptions and commentaries relate to a very difficult task - how do the members of the lower ensemble act to equilibrate the force of authority of the upper system, and yet survive to satisfy their own needs? That remains again and again the central analytic problem of homeokinetic physics.

Hopefully the reader may recognize that we have offered principles and prescription to conduct or at least realistically face the conduct of a life system. It has offered a scientific rationality, with as realistic a morality as any religion. Some will consider it another utilitarianism. Perhaps. It offers the utilitarian principles required to succeed in preserving systems, as long as they fulfill basic needs of both the individual and the societal system.

For perspective, we might offer you the views of 'pure' economics. The conventional economic thesis is that credit (and money) is put forth independently by the banking institutions because of investor demand (in new plants, etc.). Thus, as economists see it (monetary economists), impedance (diffusive costs, such as time delay, or monetary costs – the 'cost' of money now is money later, often more money) must develop to that flow. Here in the USA, the current process is a strong tinkering by the Government policy to raise the price of money now.
(prime interest rate). This, in their view, is fairly tightly coupled to employment. So the people (poor people) pay. Other classes scurry to find ways of protecting their store of value-in-trade (Gold? Art? Land? Foreign money?)

Alternate solutions are not considered. They involve other ways of managing the economy. Since in the USA, economics is viewed through the notion of a 'free market' it is amusing to watch the ways in which the market is managed and yet still not viewed as 'socialist' (a common manipulation of the modes of production, etc. - the etc. means that one or more aspects of the system can be manipulated, e.g., also consumption, etc. – by the people or delegates), or 'state socialist' (a different group of manipulators). So other manipulations will not be named. They are intrinsic to the dynamic processes, and would be viewed as socialist by some, not so by others. Again this is not a "How to...” book for real, just the beginning of principles. But we will offer one note, as a technical reminder.

Inflation, which has finally reached the current American consciousness (having existed many times elsewhere) sharply indicates the independence of the value-in-trade (symbolic) variable and the other real variables. It also indicates, in a technical sense, that the relational (mathematical) complexity increases fantastically with the addition of 'just' one new conservation. Note that this conservation is one only made up in the mind, a property that emerges from the epigenetic value potential. So at various times, people have suggested attempts to reduce the relational complexity (technically this would be referred to as making one variable a degenerate variable). How? By making it rigorously proportional to one or another of real variables. Thus there are the themes of using a Marxian labor (human action) theory of value; or the technocratic energy theory of value; or a more current indexing schema that might tie value to a 'market basket' unit of survival. This can only be done by general agreement. It is seldom one that those who monopolize access to any particular need are willing to recognize. The trouble? Free markets, with many being able to put and take equally, are long gone.
Chapter Thirty-three – A Moral Message – What to Believe

The dangers of taking these notions seriously is that they tend to create a great depression. One arrives at a sense of complete futility of 'it' all, a sense of being disanchored from a religious-moral-ethical base. But these need not be so.

One can sense, as an alternative to the notion of a singular God, a real unity in all processes - those out there and within you. That can be the source of a true sense of real harmony -of you with yourself, with your spouse, your family, your society, your species, your world, even your universe!

Systems maintain balance wherein they do not devour each other – until each is permitted a lifetime. To this extent there is a fittedness, and ethicality to all existence.

If each structure has its own time and place in the history of the development of the universe -each perhaps with its own space and time - each is equal to any other in its space and time. Each of us is as worthy as any other; and similarly one to each other.