EMBODIMENT OF FREEDOM

SUMMARY

Freedom is factual and shown through examples: Mom at the market choosing between apples and grapes, a ping-pong player swinging into a stroke at an incoming ball and a federal court Judge deciding a formal Motion in Court. The facts of freedom are: in each example, a ***selection*** is being made (two or more possible deeds are changing into a single actual deed); there is a ***critical moment*** of selection (which may extend from a split-second in ping-pong to days for judicial deliberation); and there are various ***influences*** bearing on the selection during the critical moment which shape the conscious experience of a ***person*** who makes the selection and exercises freedom.

Accounting for freedom is a chief goal of constructions presented in these pages, constructions that model a person exercising freedom. The models have both a ***physical*** aspect — governed by physical principles that also govern activities of brains — and a ***psychological*** aspect — using psychological principles to describe the experience of a person exercising freedom. Both aspects are governed by a single set of Principles that unite psychology and physics with common concepts and a common vocabulary, e.g., "selection, "critical moment," "phases," "tiling," "resemblances" and "cyclical selection."

The psychological aspect is based on teachings of Jean Piaget, a pioneer of child developmental psychology. The developmental approach begins with a focus on coordinated activity of senses and muscles, called sensory-motor activity. Sensory-motor experience is modeled by ***deeds*** that combine particular sensory perceptions with particular muscular actions, e.g., touching a ball, reading a word aloud. Deeds are structured through repetition – e.g., footsteps during a walk or a stacking routine used for washing dishes, which arises from ***cycling*** of an organism's sensory-motor apparatus. In ongoing cycles, a person can select from variations that resemble one another, e.g., selecting the next key to strike on a computer keyboard. Selections are sequenced to generate a result, e.g., a sentence of text. These can be exercises of freedom.

The physical aspect is based on principles of ***thermodynamics*** – which are different from the principles of mechanics that are generally believed to be the essence of physical science. Mechanics implies a commitment to a view that reality is constituted entirely by tiny particles, causes and chance. Thermodynamics needs no commitment to such a comprehensive view of reality and the account presented herein expressly abstains from such commitments. Rather, the approach is through "ideal" systems that have a focus of application but only a limited reach. Carnot's Ideal Heat Engine is the model for activity of brains that resembles, not computers, but energy-converting engines, modeling the generation of deeds by cyclical energy conversions. ***Critical point principles*** that have been intensively investigated by physical scientists and mathematicians provide a physical model that can be grasped visually without need for scientific or mathematical knowledge. Critical point principles are generalized into Principles that show how a person, as a matter of fact, exercises freedom.

CONTENTS

Part One: Features of Freedom and Their Embodiment

1. Examples of Freedom: Mom at the Market, a Ping-Pong Player and the Judge

There are enduring questions about the meaning of freedom and about how freedom co-exists with natural science. I have a new approach to these questions that begins with three examples. In each example a person is exercising freedom. We view events as they are happening.

1. A mother is shopping at a grocery store, accompanied by a fidgeting child. Having stopped at a bin offering table grapes at $2.69 a pound, she has a package of grapes in one hand, while, with the other hand, she holds a bag of apples she picked earlier that cost $1.49 a pound. She will buy grapes or apples but not both; and she is now choosing between them.

2. A ping-pong player has just completed a stroke, having hit the ball during a volley in a tournament game. He is seeing his opponent in motion while performing the return stroke and, in anticipation, he is starting to move his lower body to the left (in response to the opponent's motion) while, with his right arm holding the paddle, he starts into a swing that, as it continues, he will turn into one of several ping-pong strokes, such as a loop, a smash or a flip.

3. A United States District Court Judge is reviewing a request or Motion made by one side in a civil lawsuit, asking the Judge to order that a certain procedure be done earlier in the case than is the norm set forth in the rules, which also allow for an exception "for good cause." The other side opposes the Motion. The Judge can grant the Motion or deny the Motion; and she can find sufficient justification in the facts and in legal principles to support either decision.

In each example, two or more possible courses of action are changing into a single actual course of action. When one of the possible courses of action becomes the actual course of action, the other possibilities cease to exist even as a possibility. Each change is produced by a ***person exercising freedom***.[1] Such changes, persons and freedom are the subject matter of these pages.

Mom's decision in the grocery store is an example of a general kind of freedom that persons exercise in all markets. The ping-pong player's stroke is an example of a general kind of freedom that persons exercise in all games and sports. The Judge's ruling is an example of a general kind of freedom that persons exercise in all courts and during many governmental determinations. Other examples could be based on travel adventures in cities or in wilderness; on scientific and professional work; and on creative and performing arts. I suggest that such exercises of freedom make up a substantial part of many a person's conscious activity. I suggest that markets, game rooms, sport fields and courts, as examples, are instituted to organize and cultivate such exercises of freedom.

[1] ***Boldface-italics*** is used to signal the introduction of an important word or phrase.

2. Features of Freedom: Selection, the Critical Moment and Influences

a. Selection. Formally, a ***selection*** is a ***process*** during which two or more possible courses of action change into a single actual course of action. [A process is a succession of conditions in time, e.g., during cycles.] Prior to a selection, there are two or more possibilities. After the selection, one of those possibilities has become ***the actual result***. Other possibilities have ceased to be possible. During the selection, a person exercises freedom called ***selectional freedom***.

b. The Critical Moment. A selection occurs during a period of time, the ***critical moment***. The critical moment is difficult to define directly so an indirect definition is used. There was a time before the selection when there were possible deeds but no actual deed. At a later time, after the selection is complete, possibilities do not exist but an actual deed has been performed by the person. After completion of the selection, there has occurred, historically, a succession of stages in time and the "before" stage is separated from and distinct from the "after" stage. In between the "before" and "after" stages, there is an interval of time during which the selection occurs. It is during this interval that the critical moment occurs. The critical moment may last a split second (as in the case of the ping-pong player), a few seconds (as in the case of Mom at the market) or may extend over a prolonged period of deliberation (as in the case of the Judge). The critical moment is within an interval of time that begins with one state of affairs, in which there are two or more possibilities, and which ends with a different state of affairs, in which there are no possibilities but one actuality. The edges of the critical moment are not well-defined but it is clear that the interval exists within which the change occurs.

We encounter difficulties when we try to look into the critical moment. There seems to be an unbridgeable gap between (1) a person considering multiple possible courses of action in thought or through mental imagery, on the one hand, and (2) the person carrying out a single selected course of action through bodily movement, on the other hand. Some have discussed the gap as part of the "mind-body problem." The gap identifies a problem we have in understanding how possible deeds turn into actual deeds — but factually, every day, in many ways, every person is continually bridging that gap. In § 7(c), I present a unified psychological and physical account of the gap and of how we bridge it.

c. Influences. The actual result of a selection often depends on a person's consciousness of matters that the person can identify, e.g., in later conversation or in a written description. The person may (but need not) actively consider such matters during the selection; and the person's considerations often lead to the actual result. As a spotlight on the way this works: sometimes a person neglects to consider a certain matter during a decision and recognizes later that, if that matter had been considered, the actual result would have been different. Without an attempt at an exact definition at this point, I say that such matters are ***influences*** on the selection.

Using the examples from § 1, Mom selecting fruit in the market may be influenced, e.g., by her taste preferences or the taste preferences of members of her family, by the food budget, by theories of nutrition and health, or by the anticipated visual appearance of the fruit in a particular bowl. Perhaps Mom decides to buy grapes to please her sister who is coming for a visit.

The ping-pong player selecting a stroke may be influenced by the difficulty of returning the opponent's shot, by the opponent's position across the table, by the player's recent history of success or failure of various strokes, by the score of the game, or by a sense of prowess in comparison with that of the opponent. Perhaps the ping-pong player goes for the loop because he is behind 9-8 (11 points wins the game), he feels that he can't make a mistake, he sees that he can meet the incoming ball squarely with a loop and the loop is his most reliable stroke.

The Judge deciding the Motion asking for an early use of a procedure may be influenced by Opinions (formal explanations of decisions) written by other judges deciding a similar issue in earlier cases, by factual or legal presentations of the lawyers, by expectations about the future course of events in the case, or by general judicial policies such as a policy of discouraging requests for special treatment. Perhaps the Judge denies the Motion without giving a reason but actually because the lawyer for the party making the Motion is trying to overwhelm the other side; and the Judge also schedules a case management conference (a private meeting with the lawyers) during which she will deal with the issue presented by the Motion in her own way.

d. Idealized situations (cycling activity). Sometimes, it is possible to consider variations in the influences and how varying influences might lead to different selections. The clearest examples involve ***approximately repetitive selections***. That is, a particular situation involves a certain selection that occurs repeatedly but where influences vary. The actual result will remain the same, up to a certain point; and then, suddenly, a further variance in the influence will lead to a different actual result. Such activity is modeled by repetitive cycles and ***cyclical selections***.

These principles are illustrated by adapting the three examples of § 1 to approximately repetitive selections and including also, in each example, a second kind of selection. Suppose Mom is now selecting potatoes from a heap of potatoes, examining one potato after another and picking out the best; but if she finds none that meet her standards, she will leave the potato bin. Suppose the ping-pong player is now practicing with a partner who repetitively drives balls into a certain area of the table for the player to try a variety of responsive strokes; but if nothing is challenging him, the ping-pong player will try a different exercise. Or suppose the Judge is now quickly deciding a series of Motions, each asking for a delay in the scheduled trial date; but if one is unusual, the Judge may re-schedule the Motion for further inquiry.

In each of the adapted cases, selections occur repetitively (cyclically) and under a set of circumstances that is largely fixed. Of course, each selection is unique. The repetition and similarity, however, enable the person to aggregate and to compare and contrast a large number of examples, seen together as a single subject matter. The aggregation is what influences the second kind of selection that results, e.g., in Mom leaving the potato bin, the ping-pong player trying a different exercise and the Judge re-scheduling a Motion.

In Part Two, idealized repetition fills time and space as a chief Principle for construction of models, a Principle called Tiled Embodiment. Space, time and activity (deeds) are ***tiled*** in both physical and psychological aspects. Multiple tilings — where features of one tiling can vary with respect to another tiling — are combined to generate families of deeds in cyclical forms. E.g., a children's song like "Row, row, row your boat" that can be repeated indefinitely.

e. **Preview:** The definition of selectional freedom is the first step towards an ultimate goal, the construction of working systems — a class of "engineered organisms" — that interact with their environment in ways that resemble biological organisms. An engineered organism has both a physical aspect (operating according to physical principles that govern brains) and also a psychological aspect (that correspond to a person's experience). Technical details of engineered devices are presented in *Quad Nets* and *Timing Devices*. Here, I set forth the psychological and physical principles, but without technical details. Physics is integrated with psychology through Principles that apply to both aspects.

Models of biological organisms are also based on the Principles. In engineered and biological organisms, an elemental unit of a course of action, in both physical and psychological aspects, is a ***deed*** of the organism. As a structural unit, a deed is suitable for assembly into a larger-scale course of action. As a simple case, a footstep is a deed and a sequence of footsteps is a sequence of deeds, e.g., walking on a path from A to B. Many deeds involve selectional freedom, e.g., Mom chooses the grapes; the ping-pong player hits the ball with a loop stroke; the Judge denies the Motion. Deeds are typically organized by reference to a particular task in a particular place, e.g., organized by reference to a shopping list, a tournament or a daily calendar of Motions.

The "deed" concept is defined developmentally, that is, with an initial core definition and with subsequently defined extensions from the core. At the core, an organism performs a deed through coordinated (1) perception of a sensory object and (2) execution of a motor act. E.g., "I go to one who calls my name" or "I strike a key on my laptop computer."

Development of the deed concept begins with simple activity like that of rudimentary animals. The Principle of Resemblances discussed in Part Two leads to increasingly complex activity. In brief, the Principle of Resemblances states that, in operation, ***brains generate families of activity patterns, with members that are related by resemblances***. There are various kinds of families, e.g., a family with children, a family of companies, a family of colors or a family of equations. A family of possible deeds is a ***repertoire***. Often, a person selects one deed from a repertoire. E.g., an automobile driver waiting at a traffic signal is continually selecting from a repertoire of two deeds – "stop on red" and "go on green." Each selection is made up of (1) an object (red/green) and (2) an act (stop/go). This selection is controlled by the traffic light; the three examples of § 1 show free selection. The traffic light repertoire is the chief example for detailed analysis in § 7 that shows what happens during a critical moment.

In Part Three, the initial core definition of a deed is extended to structures and sequences of objects and acts such as habits, chores, incidents, scenarios and Piaget's "schema". E.g., walking from A to B is also a deed. Further extensions lead to indirect perceptions (e.g., through symbols) and indirect executions (e.g., with tools). ***Imagination*** is introduced as a variant of reality but with lesser constraints; and deeds can be more easily performed partially or wholly in imagination. Extensions are based on Principles of ***organizational freedom*** that include a Principle of Balance and a Principle of Integrity.

3. Psychological Principles: A Person Engaging Reality

A Person. The primal psychological concept is that of ***a person.*** A person makes the selections in the examples of § 1. There is no definition of "a person" better than our first-hand knowledge. We all know a person when we meet one. Each of us says, "I am a person." I believe that there is a capacity shared by all adult human beings with a reasoning mind that enables us to recognize each other as persons. These pages are presented for the benefit of persons sharing that belief.

Reality. As discussed in § 2, when a person makes a selection, two or more possibilities change into a single actual result. Often, a possibility must be excluded from becoming an actual result because of a ***prohibition*** arising exterior to the person, e.g., lack of needed material objects and/or "No" from another person. I construct the concept of ***reality*** to collect such prohibitions. That is, reality is exterior to a person making a selection; and reality prohibits some actual results that the person might imagine. More generally, I say that reality ***constrains*** selections. Hence, a "law" or "rule" is a ***statement of constraint***, based on prohibitions, that limit possible courses of action in a selection. Sometimes constraints on a selection prohibit all actual results except for a single favored possibility and then the selection is ***determined***. Although stated categorically, these definitions are based on differences in degree that can be systematically varied. In a fully determined or deterministic system, all imaginable possible courses of action, except one, are prohibited; and that one imaginable course of action is compulsory.

In other words, reality, often in the form of a law or a rule, excludes courses of action that might otherwise be selected. E.g., gravity, part of reality, constrains us to remain on solid, supporting surfaces and we cannot levitate like birds or insects, no matter how strong the longing. When two persons interact, one person's selections constrain the other person's selections, e.g., during a game of checkers. When only one course of action remains, that course of action is determined; otherwise, a selection is made from two or more possibilities allowed by reality.

Unless otherwise stated, the meaning of "possibilities" is limited to possible courses of action (or possible deeds) of a person that are within the constraints imposed by the person's reality and that are, therefore, ***realizable*** possibilities. I imagine many deeds that I will never realize.

Each person has his or her own reality but some parts of a person's reality are shared with other persons. There are different kinds and levels of sharing, e.g., reality shared by persons living together in a family, a school district or a country; there may be a distinct reality specific to a religion, ethnic group or lifestyle; or to young and old. The differences enable us to divide reality into ***aspects*** of reality. The differences are the basis for ***disputes***, which in a larger-scale application of Principles, are vehicles of change in an organization of persons. E.g., one side says, "we want to do *x*" and the other side says "you must not do *x*."

Important aspects of reality, called ***universal***, are shared by all persons with a reasoning mind. Chief universals are ***space*** and ***time*** and ***material objects***. We all agree that space and time and material objects are real; we use common units to measure them; signs and signals of space and time are common public resources; and mass-produced material objects of uniform kinds, e.g., clothes and computers, are widely distributed and in common use. Constraints are often based on these aspects of reality, e.g., "not enough time," "too large" or "can't afford it."

The ***primacy of persons*** is universal, shared by all persons with a reasoning mind. Every selection is influenced by the desires, needs or fears of a person or persons or group of persons. For each of us, his or her own person — one's self — "I" — is the continuing central originator of selection. Each person knows that each other person is motivated by self-interest and by the interests of that person's loved ones. Many of us have strong commitments to groups of persons, which are shared by others in the group. A person's committed relationships with other persons are typically among the most powerful influences in a person's selections.

A person's body calls for special consideration. Each of us knows his or her own body in ways that are indescribable but much the same for all. A person's body is a material object and it is also part of the person that is essential for everything in the life of the person. Reality imposes constraints on us through our bodies beginning with Mom and concluding with bodily failure. Our shared bodily nature is part of our shared reality and a ground of our capacity for empathy and community. Each of us understands, at least approximately and based on one's own experience, how sensations and feelings in another person will arise from that person's bodily experience and how those sensations and feelings will influence that person's selections.

A person's body is the means for the person to interact with reality. There are several means of interaction, including internal bodily systems like the digestive and immune systems. Here, the focus is on chief external bodily systems, namely (1) ***sensory*** systems and (2) muscular or ***motor*** systems. Activities of these two kinds of systems are coordinated during ***sensory-motor activities***. Sensory-motor activities generate deeds, the psychological units introduced in §2.a.

In a person's experience, sensory-motor activities have, at their core, basic animal capacities for moving one's body and orienting oneself with respect to gravity, light, sound, etc. Sensory discrimination adds refinements, especially through symbols. Each person learns additional skills like those of the ping-pong player, the mother and the Judge. Development of additional skills does not reduce the importance of sensory-motor skills. All human psychology begins with sensory-motor activity, according to Piaget. Even rudimentary animal lives, e.g., those of jellyfish and sponges, are built around sensory-motor activity. The motor activity may be simple like Mom's in the market putting one item aside and the other in her cart, precise like the ping-pong player's accurately directed stroke or indirect, e.g., the Judge tells her assistant or "clerk" (who does the writing) what she wants in her ruling and Opinion. Sensory-motor concepts are even built into legal doctrines used by the Judge, who may say that the facts in one prior decision are "closer to the present case" than those in another prior decision or that "the trend of the law is moving away from your position, Mr. Lawyer."

A ***situation*** is a part of reality that imposes continuing constraints on a person's selections. While a person in a situation is continually making selections subject to such continuing constraints (as well as subject to transient influences), the person is ***engaging reality***. Markets, game rooms, sports fields and courts sustain situations in which persons engage reality. While exercising freedom, through selections made within constraints, a person in such a situation repeatedly changes two or more possible courses of action into a single actual course of action.

4. Physical Principles: An Alternative Approach

Principles of physical science are adapted to model a person's exercise of freedom. Based on thermodynamics and materials sciences (e.g., metallurgy), the principles are presented with technical details in *Quad Nets* and *Timing Devices*.

The principles of thermodynamics and materials sciences are distinctly different from physical principles that are far more prominent in the public eye and that almost completely dominate discussions of physics and science in general literature and in journalism. To distinguish the two kinds of principles, I call the predominant body of physical principles ***the conventional view*** in contrast to the view that I present, which I call an ***alternative view***.

Proponents of the conventional view created and developed systems of ***mechanics***, e.g., Descartes, Galileo, Newton, Euler, Lagrange, Hamilton, Jacobi, Boltzmann, Einstein, Heisenberg, Schrodinger, Dirac and Feynman. The alternative view is based on work of a less celebrated line of scientists who created and developed ***thermodynamics***, a line that includes Robert Boyle, Joseph Black, James Watt, Joseph Fourier, Sadi Carnot, James Joule, William Rankine, Rudolf Clausius, William Thomson (Lord Kelvin), James Clerk Maxwell, Lars Onsager and Kenneth G. Wilson – and also Clifford A. Truesdell III, who especially guided me though his writings. Truesdell belongs in a class of one, as does Josiah Willard Gibbs, whose highly innovative, but limited and focal system incorporates both mechanics and thermodynamics. Some of the work in the less celebrated line has been called "pure thermodynamics" and my approach draws on that purity.

The conventional view starts from a premise that everything is knowable. In the easiest initial problems, all quantities are specified with exactitude through a single formulation; and many scientists hold to the belief that a single comprehensive formulation can be stated. The alternative view starts from a premise that only a little bit is knowable, but also that the little bit may be a most important bit for practical purposes. Thermodynamics focuses on what can be made clear; and pure thermodynamics stands silent on or abstains from many questions.

The alternative view (adhering to thermodynamic principles rather than to mechanical principles) is reflected in the alternative approach to modeling brains with engineered devices. The conventional approach views a brain as a machine, e.g., a computer, leading to a system of computers. The alternative approach views a brain as a ***thermodynamic engine*** leading to a system of such engines. The two approaches are not opposed to each other and can even coincide in some ways, but the underlying conceptual bases are quite different and each does things the other cannot. Mechanics works poorly at describing ***phase changes***, which are a chief subject matter for thermodynamics and discussed in the next section. Fortunately, there is one point – the ***critical point of the Ising Model*** – where the two approaches coincide and that point is a germinal focus of the presentation.

Machines fit into a system of causes and effects. That is, in mechanics, "law" has a causal meaning rather than the constraint meaning introduced in § 3. The simplest machine is a lever, where you push at one place and move a weight at another place — causality illustrated by a teeter-totter. Computers are machines where symbolic commands cause specific actions.

Computers are not engines, as I use that term, even though computer designers have put the name "engine" on their creations, from Charles Babbage's "Difference Engine" to the latest "search engine." A computer is a way of organizing activity through causal links, e.g., in the form "If x, then y" or similar programming methods. In the conventional view, the computer's organization reflects the organization of reality, in the form of a texture of mechanisms that governs the motions of passive objects (plus effects of chance events.) Machines embody mechanisms. Conventional mechanics is the physics of mechanisms and of cause and effect.

Of course, I use mechanisms as conceptual units. Causal relations, in my view, arise naturally in our intelligence and serve as very useful tools in dealing with reality. Mechanisms take the seats of honor at the intellectual symposium. The problem is that mechanisms are just not suited to dealing with the phenomena of freedom. Freedom and mechanism have a complex relationship and are often oppositional concepts: if mechanisms completely govern the acts of a body, there are no multiple possibilities, there is nothing to select and the body is devoid of freedom. Hence, the alternative approach abstains from reliance on mechanistic principles or on causal relations. Pure thermodynamics is silent as to the existence of underlying mechanisms.

Engines, as I use the term in a thermodynamic sense, are not machines. Rather, an engine converts energy from one form into another, e.g., an internal combustion engine in a car converts chemical energy stored in gasoline into energy in the form of vehicular motion. A steam engine converts heat energy in steam into mechanical energy. As I see it, a brain converts energy in the form of blood sugar into neuronal pulses that drive muscles according to sensory input and other influences, e.g., memories. I suggest that activity in brains is similar to that of a vehicle engine that propels the vehicle according to the driver's selections. Mechanisms may be involved but the essential activity is energy conversion that makes certain energy available for selection plus the selections that direct such energy in certain ways. In brains, I suggest, the driver is embodied in the engine. Through constructions set forth herein, I suggest that a person dwells in a brain.

Please note that thermodynamic concepts of energy, like mechanical concepts of causality, are constructions of human intelligence with limitations, omissions and defects that are characteristic of our concepts. However, some problems with the energy concept can be minimized through principles of cycling, equilibrium, reversibility, continuity and the like that have a basis in thermodynamics. My proposals seek to take advantage of such principles and to model activities of brains using energy-converting cycles, like those in Carnot's idealized models of heat engines, and not using causal links, like those used in computing machines that embody mechanisms.

Proposing to model brains with computers that embody mechanisms, the conventional view has no tools to account for selectional freedom. Mechanistic theories cannot account for the ping-pong player's quick selection of a stroke. During exercises of freedom like those of Mom in the market or the Judge in her courtroom, a person makes selections to harmonize his or her desires, concerns, etc. but such harmonization occurs in a domain of experience, thought and feeling where freedom is implicit. To try to "derive" a person's consideration of such influences from differential equations or computer-like commands would reduce any decisional power of the person to a meaningless self-delusion. There is an irreconcilable clash between the facts and features of selectional freedom set forth in §§ 1-3 and the conventional view, where reality is a texture of particles, mechanisms and chance.

5. Physical Principles of Collective Change — Bodies and Phases

Ideals. Mechanics (discussed in § 4) is organized, in part, by reference to ***force laws***, such as the gravitational force law, the Lorentz force law and the strong force law. Here, in contrast, thermodynamics is organized, in part, by reference to ***ideals***. Thermodynamic ideals include the Perfect Gas, the Carnot Engine, the Crystalline Lattice, the Black Body and the Ising Model. I propose Quad Nets as a new thermodynamic ideal. A useful thermodynamic ideal is a simplified mathematical construction, but it models a certain kind of phenomena and it is based on an integrated system of concepts that supports development.

Bodies. When scientists with conventional views discuss thermodynamics, they do so in terms of Laws, chiefly The First Law of Thermodynamics and the Second Law of Thermodynamics. Such Laws mimic Newton's mechanical Laws and are of secondary importance here. (Truesdell & Bharata derived the Laws from operations of an ideal Carnot engine.) The alternative approach starts with physical material, collected into a ***body***. Here, we examine only bodies that have a form of compact unity; ideal examples are solid balls and bars but, more generally, stretching is allowed. The chief foundational characteristic of a body is that there is a ***bodily surface***, like a skin, that bounds the body within its ***environment***. Typically, physical materials and/or energy pass through the bodily surface, but only in controlled or measurable ways. Such passages of physical material and energy through the bodily surface ***couple*** the body to its environment, which can include other bodies. Body, bodily surface, environment and coupling are concepts that all arise together. Here, a body is always coupled to an environment, at least implicitly; a person is always engaging reality; and deeds are always specific to a situation.

We focus first on a ***homogeneous body***, which is all of one piece of physical material at any moment. Observable quantities such as temperature, pressure and mass density apply to an entire homogeneous body and are uniform throughout the body. There are also variable conditions or ***phases*** that characterize the body as a whole — such as a solid phase, liquid phase or gaseous phase — and that can change in important ways. Ice, liquid water and steam phases of H_20 are the obvious, familiar example.

Several homogeneous bodies can be joined or organized to make up a collective entity that has a bodily surface coupling that entity to its environment; this is a ***heterogeneous*** body made up of homogeneous bodies. Each homogeneous body retains its distinction within a heterogeneous body, at least initially. Such construction is the origin of bodily structure. The concept of structure used here allows for a bodily surface defining a heterogeneous body to be imaginary and subject to arbitrary step changes so long as such bodily surface is well-defined at each step.

The foregoing definition of the word "body" is sufficiently broad so as to include a human body, a brain, a Quad Nets device part that mimics a part of brain, a piece of metal alloy or a volume of gas in a cylinder. A human body is not homogeneous; but a piece of metal alloy and a volume of gas are each homogeneous.

In brain models, a brain is a heterogeneous body with a single energy source that is made up of homogeneous brain parts, which are anatomically connected by nerve fibers between pairs of parts, forming a network. While the person is engaging reality in a particular situation, a subset of parts participate together and make up an ***activated structure*** of brain parts, discussed below.

In thermodynamics, ***phase changes*** identify changes in the condition of a body occurring when the temperature is changed. Most important, a very small change in temperature causes big changes in the condition. E.g., with only a small increase in temperature, ice changes to liquid water or liquid water changes to steam. With a forward look toward later statements of principle, I suggest that the gap between possible deeds and an actual deed is no more unbridgeable than the gap between liquid water and ice and that there is a single thermodynamic view of both gaps.

The terms "phases" and "phase changes" describe broad classes of factual phenomena seen in physical materials. Many different materials undergo changes that can be described by the concepts of phase and phase change: a certain small variation in the temperature and/or other external influences result in an overall change in the body's condition. In addition to liquids and gases constituted by chemical re-agents (e.g., water, CO_2, nitrous oxide), the phase concept describes properties of metals, which melt and solidify in diverse forms called ***alloys***. Other materials, such as ceramics, glasses and gels are also defined by their phases and phases changes. Phases in magnets are discussed in the next section.

Hans Haken and his students have used the concepts of phase and phase changes to study brains and behavior. A simple phase in human behavior is a repetitive finger pattern movement, e.g., putting hands side by side and waving index fingers up and down either in the same direction or in opposite directions. The tempo can be driven by a metronome.

Engaged in colloquial conversation, persons use the words "phase" in much the same way : a certain condition (of one's life, of the economy, culture, society, etc.) goes along in a fairly constant way for a certain period of time, and then, quickly, things become different. That was a certain phase, we say, and now things have changed, we're in a new phase.

Comparing phase changes in materials to processes of selectional freedom (§ 2.a) shows important shared features. The course of events during a phase change is not only of "critical" importance, it is also difficult to understand. If phase changes take place quickly but under controlled conditions – e.g., while quenching a mixture of hot iron and carbon to produce steel – the course of the change can be followed but only in a limited way – e.g., as originating in multiple scattered "nucleating events." The course of events, like the process of selectional freedom, is centered around a short period of time during which various possible arrangements resolve into a single actual arrangement.

6. The Critical Point in Magnets

A bar of magnetized iron at room temperature will pick up and hold a certain number of steel thumbtacks but no more than that number. If one additional thumbtack is put up to the magnet and released, one will fall away, either the additional one or another one. Let the ***magnetization*** of the bar at any moment be equal to the number of thumbtacks the bar will hold at that time.

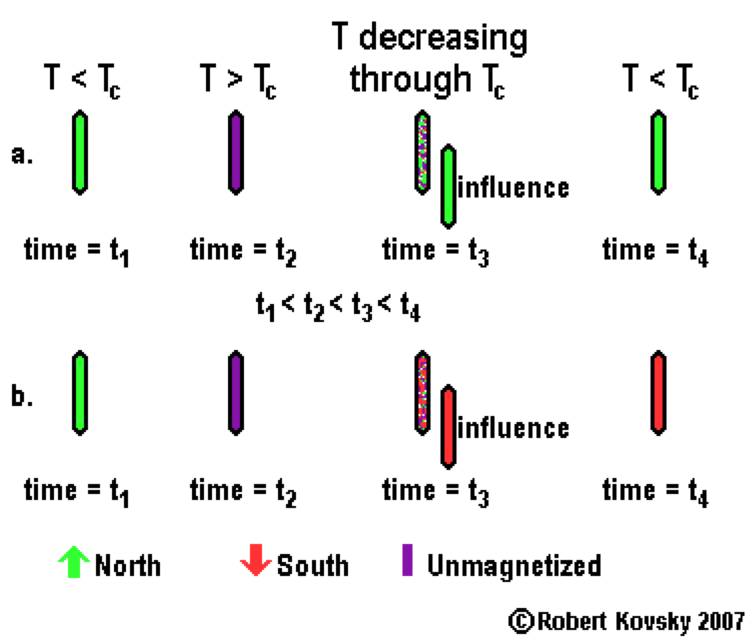
If the temperature of the iron bar is progressively raised, the magnetization will gradually decline and some thumbtacks will fall off, up until the temperature of the bar reaches a certain ***critical temperature***, denoted T_c. As the temperature of the iron bar reaches the critical temperature, the magnetization vanishes and all the remaining thumbtacks fall off together.

If the temperature of the bar begins above T_c and is lowered, the iron bar can be re-magnetized. The re-magnetization occurs at just the same critical temperature T_c that marked the transition in the upward direction. If there is another magnet nearby as the temperature is lowered, the iron bar will become re-magnetized as result of, and according to, that other magnet's influence.

Such changes in magnetization occur throughout the bar at one time and as the temperature passes through a very narrow range of temperatures around the critical temperature. At the critical temperature, the condition of the material is said to be at ***the critical point***.

In idealized imagery in Image 1, an iron bar is initially magnetized with a north magnetization. Except at the critical point, a north magnetization excludes a south magnetization, and vice-versa. When the temperature of the bar is raised to above the critical temperature, T_c, the magnetization vanishes. If the temperature is then lowered, the influence of a nearby magnet re-magnetizes the bar, with the polarity (north or south) in the re-magnetized bar the same as that of the nearby magnet.

Image 1: Magnet cycling around the Critical Point (T_c)



Two different cycles are shown in Image 1, both beginning with a north magnetization. Other cycles would start with a south magnetization at time $t=t_1$. In all cycles, as T decreases through T_c, the material goes through the critical point. In each such cycle, there is a ***critical moment*** during which the phase change occurs. That is, a critical moment is defined within a cycle.

Image 1 shows an important feature of the alternative approach. Suppose the question is asked:

"why does the magnet take on a south polarity in Image 1.b?" There are two answers to that question: (1) because of the decrease in temperature through T_c; and (2) because of the presence of the nearby south magnet that influences the selection. Without making a commitment to the reality of causes, it is possible to speak of the decrease in temperature as a ***driving cause*** and the influential nearby magnet as a ***selecting cause***.

Applying this analysis to the ping-pong player (§ 1), his selection of the next stroke is caused in one sense (the "driving cause") by the impending arrival of the ball and, in a different sense (the "selecting cause"), by the various influences discussed in § 2(c), e.g., the score. Similarly, Mom's decision in the market is driven by deadlines and her child's restiveness; and the Judge's decision is driven by a busy calendar. Both the driving cause and the selecting cause are effective during the critical moment; but the effect of the driving cause is to bring about the occurrence of the critical moment; while the effect of the selecting cause is to bring about the occurrence of one actual deed out of multiple possible deeds, excluding other possible deeds.

Looking forward, brain models are designed to work while cycling, with variable rhythms, speeds, "timing intervals" and "interactions." In these designs, a driving cause is the cycling of a control parameter that corresponds to a cycling temperature in studies of material bodies. E.g., in magnets like those in Image 1, the test temperature goes up and down cyclically. In Quad Net device parts, there is a quantity that controls conditions in each device part — ε is the symbol — that is like a temperature and that varies cyclically and repetitively up and down. Variations in ε can be imposed by a researcher or by other device parts. Each time ε passes downward through 0, the critical point, the device part generates an actual signal selected from possible signals according to influences then bearing upon it.

The separation of the driving cause from the selecting cause means that one cause can be varied independently of the other cause. The driving cause can go up and down while the selecting cause remains the same and the selecting cause can change while the driving cause (temperature) is fixed. As discussed in § 7, this independence can model a person changing his or her mind, where a system fixes on a course of action and then returns the driving cause to the critical point, commencing to run the cycle again with some revised influences.

The condition in the part of the cycle just before selection is called ***readiness***. Psychologically, "readiness" is anticipation that awaits particular action, e.g., waiting at the traffic light. In magnets, readiness corresponds to the unmagnetized condition when the temperature is above T_c. In proposed models using QN device parts, readiness (e.g., during tiled activity) designates a condition where elemental devices are approaching discharge. Readiness is universal, presumptively the same for all persons in multiple contexts, and incorporated into processes of intelligence. A readiness condition is implicit in the exercises of freedom described in § 1.

7. Selections, the Critical Moment and Influences: In Personal Freedom as in Magnets

a. Cyclical selections used to model a person's activity

A single collection of critical point Principles governs critical point transitions in both magnets and Quad Net brain models. I suggest that the same Principles are operative in the brains of persons exercising freedom.

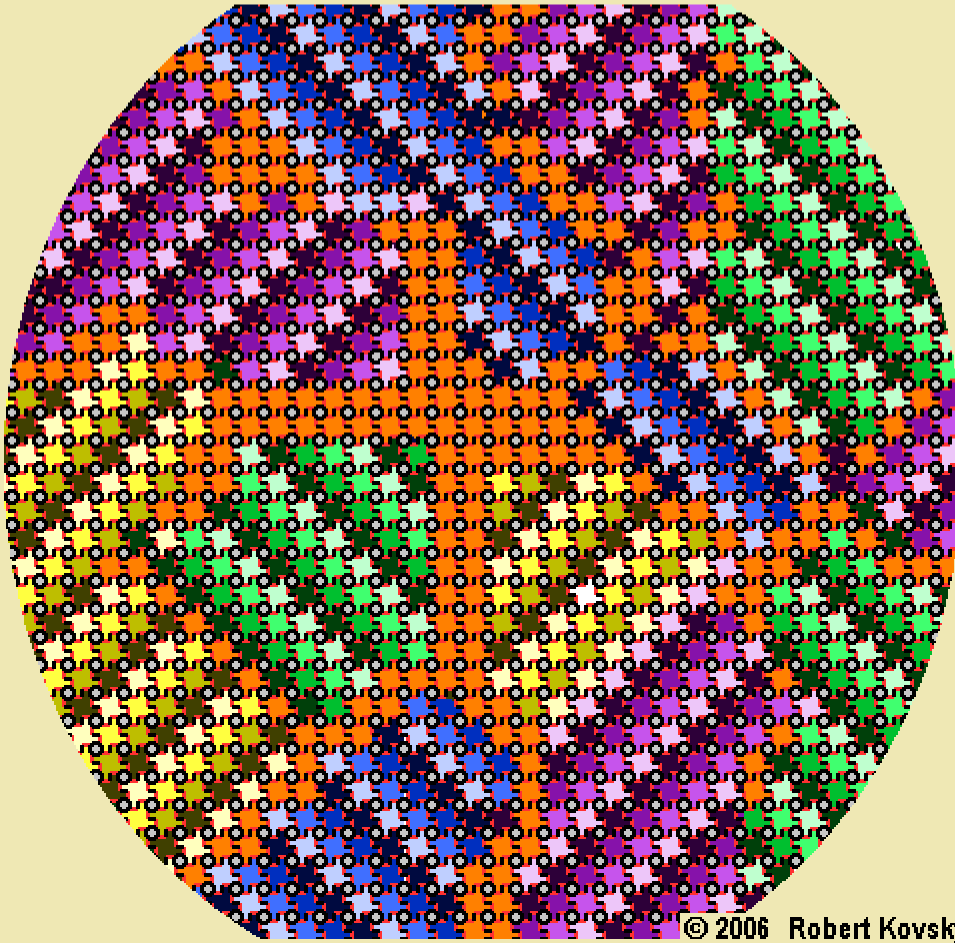
In this approach, magnets, Quad Net devices and brains are all ***cycling*** through the critical point. During idealized cycling activity, the easiest to study, there are repeated passages through the critical point, during each of which a selection occurs. There is a sequence of ***cyclical selections***. During a cycle, three ***phasic periods*** succeed each other ABCABCABCA... The body is in a distinct ***condition*** during each phasic period. The phasic periods are:

> (A) a ***specific phasic period*** during which one phase is dominant. E.g., north (or south) in magnets. There is a ***repertoire*** of phases from which one phase is selected, like north/south is the repertoire of magnets. In Quad Net devices, specific phases are activity patterns, e.g., pulse bundles moving in a particular direction and with a particular period. Some human activity patterns are organized by such a repertoire, e.g., selecting acts from "stop/go," or "forward/back/right/left move."
>
> (B) a ***nonphasic period***. No specific phase is present. E.g., when $T > T_c$ in magnets. The corresponding "silence" in Quad Net devices occurs when $\varepsilon > 0$. In cycling, there is readiness, approaching the time when a specific phase is selected. A person can be "ready and waiting," e.g., for the command of a leader.
>
> (C) a ***momentary critical point condition*** when the system is passing through the critical point and the specific phase is being selected. In magnets, $T=T_c$ and, in Quad Nets, $\varepsilon=0$. In freedom, this is the critical moment. As the cycle continues into the specific phasic period, $T<T_c$ in magnets and $\varepsilon<0$ in Quad Net devices.

The Ising Model discussed below makes it possible to examine the critical point condition that occurs as the cycle goes from B through C and towards A, as in Image 1 (§ 6). At the critical point, possible phases emerge from the nonphasic condition in fragmentary forms. Fragments co-exist and easily supplant one another or "turn into" one another. First, one phase may be dominant at a particular location and then, the other phase will be dominant. The flickering form occurs throughout the field of the Model.

Fragments in the Ising Model take the form of clusters of north elements or of south elements. Fragmentary activity patterns in Quad Net devices take the form of flickering fragments of waves or "wavelets" that momentarily co-exist, intermingle and interconvert. (Wave fragments are shown in Image 38 from the Quad Nets paper).

Image 38: Shimmering made up of flickering phase fragments



At the critical point, changes in activity are ***reversible***: the system can return to a previous condition after wandering. Only at the critical point are phase changes reversible in this activated sense. Activated reversible phase changes are the essence of critical point activity.

To preview the discussion of complex systems in Part III, towards which we are heading, suppose that, when a person is in a fixed situation (as defined in § 3), certain large-scale brain structures are activated, but many brain parts are not involved in the activated structures. The activated brain structures produce a large, collective wave pattern that drives a full-scale muscular act, e.g., a kick in swimming. To perform this act, which is constituted by many separate muscle twitches, interconnected brain parts are driven so that the selection of a particular wave pattern in one part will influence selections subsequently occurring in other parts. In such operations, there is ***sequencing*** of passages of parts through critical moments, such passages occurring one after another and so as to accumulate and/or combine the influences. These observations apply both to device parts in Quad Net constructions and to brain parts in biological brains. A rudimentary sequencing in magnets is shown in Image 4, below.

In further developments, parts assembled into a system can also have their cycles ***synchronized*** so that parts pass through a critical moment together. During such synchronized passage of multiple, interconnected parts through a single critical moment, multiple possible large scale activity patterns are produced in a way that generalizes the production of fragments generated in a single part during a critical moment. That is, I suggest that synchronized critical moments from interconnected parts unite into a single large-scale critical moment. Large-scale patterns, like fragments, can easily change into one another through reversible phase transitions. Psychologically, a person can deliberate on and select between large-scale courses of action. The repertoire of an assembly of brain parts can be much larger than the collectivized repertoire of the individual brain parts, just as the repertoire of an orchestra is much larger than the collectivized repertoire of the individual instrumentalists playing solo.

In sum, I suggest that multiple brain parts pass together through a single critical moment and that such a passage produces coordinated selections in the different parts. Such a synchronized unification of passages of brain parts through a critical moment is, in my view, the focal origin of consciousness. The initial coordinated selections are those that occur during sensory-motor deeds, namely, a coordinated perception of an object and execution of an act. (See § 2.) Consciousness develops as more parts function together in widening varieties of situations, structures, sequencings and synchronizations. As larger numbers of parts become involved in synchronized passages through the critical point, possibilities for selection grow richer. Psychologically, there is greater awareness and more freedom.

I suggest further that, in some situations, a larger-scale pattern is distributed among numerous parts and is sustained over a substantial length of time, perhaps several seconds. The numerous parts are driven, in their turn, by a pulse pattern, a ***coding***, that is generated by a different, "higher" system of parts. Activity patterns selected in the higher system drive the lower system. Passing through its own critical moments, the higher system generates an actual coding selected from multiple possible codings.

In human brains, the highest system is the cerebrum, the sheet of neuronal material folded into a thick cap over a person's brain that is used for activities like planning and language, which are exclusively human. Neurons in the cerebrum are organized in arrays that resemble the tiled forms used in Quad Nets.

In the psychological domain, I suggest that fragmentary forms arise in the experience of a person exercising freedom and that such fragmentary forms resemble images of activity in the Ising Model and Quad Nets at the critical point,. I suggest that such fragmentary forms give rise to different momentary impulses during a deliberative period. First one impulse appears and then a different impulse appears. From such impulses, using his or her ***imagination***, a person projects activities forward in time to test the further results of actually performing a possible deed. Such projections of events enable the person to make an informed selection. The imagined projections can incorporate details of an entire course of events or ***scenario*** even though other details of such an imagined course of events are absent or confused. A possible scenario can arise as a whole in the imagination of a person, even if only sketchily, in transient fragments.

I suggest that a complex assembly of cycling critical point systems has the power to generate enormous numbers of possible activities and to select among them. Fragmentary, large-scale, transient aggregates are characteristic of critical point phenomena and appear simultaneously on the scale of elementary units, on the scale of operating parts and on the overall-global scale. Such multiple appearances and the resulting relationships are called "scale-invariance" and/or "self-similarity." Principles of scale invariance and self-similarity are among generators of families of phases, related by resemblances. (See § 2(a) as to the Principle of Resemblances.)

Psychologically, scale-invariance and self-similarity mean that a person uses a single conceptual system to make selections that have different magnitudes of complexity, that reach, e.g., from Mom buying grapes to her buying a house, from a ping-pong stroke to a tournament plan and from the Judge denying a simple motion to her issuance of a major Opinion, after trial, that concludes "Judgment for defendant."

Scale-invariance and self-similarity justify comparing complex and simple systems and help justify an approach where a complex system and the simple systems that make it up are all operating according to a single set of Principles. In particular, the same principles govern phase selection in a cycling magnet and in the brains of a person exercising selectional freedom.

As to the psychological aspect, reversible phase changes, i.e., interconversions among phases at the critical point, describe the way a person changes his or her mind back and forth. Such reversibility is an important principle in the psychology of Piaget, who borrowed it from thermodynamics. Reversibility appears as a central feature of mathematics, e.g., subtraction reverses addition. Variations on the concept reach into numerous areas of life, e.g. a person "takes a move back," "starts over" or "returns to the status quo ante." Then, in some situations, a selection cycle can be run again and again, and the actual results that follow from different selections can be compared. "Context-free" concepts like "order" (first, second, third) are more refined applications.

As the cycle proceeds past the critical point, co-existence among phases becomes impossible. One phase progressively dominates and establishes itself as a specific phase, returning the system to phasic period (A). When a predominant influence is present (e.g., an external magnet), domination occurs rapidly according to the influence and the critical moment is very brief or is absent. When there is no predominant influence, e.g., when no influence is present or when multiple influences are balanced, domination may require a lengthy time or even fail to occur.

Likewise in a person's experience, a single, predominant influence will often quickly lead to a selection. Sometimes, a person "jumps to a conclusion." Balanced influences, in contrast, bring out the features of an exercise of freedom, including a final "either/or" form of a selection and a prolonged critical moment, e.g., during a deliberative selection.

At the center of it all is the critical point. In the alternative approach, the critical point is the central focus and ultimate goal of construction efforts. Whether it is a body of material, an Ising Model, a part of a brain model or a person that passes through the critical point, each is momentarily subject to single set of critical point Principles that are very different from the principles that govern mechanics. Because of its primary importance, the Principle of Universality is discussed in detail.

b. Principle of Universality

A single set of critical point Principles applies to phenomena observed in systems that are seemingly very different from one another, e.g., magnets, water/steam, metal alloys like brass. This states the Principle of Universality. In the Quad Nets model, these Principles are extended to apply to engineered systems of device parts that I suggest mimic the activities of brain parts.

The most important fact about critical point Principles is that they arise together at the critical point but appear nowhere else. In thermal materials, critical point Principles apply only at a highly specific temperature. Rounding off, the critical temperature for iron magnets is 1043 K (770° C or 1418° F) and that of water is 647 K (374° C or 705° F). Depending on the material, if the temperature is only a few degrees away from the critical Temperature, or sometimes even a tiny fraction of a degree, critical point Principles do not apply and there are no universal principles that apply to all systems. But, at the critical point, the Principles apply "the same" in all systems (with some adjustments and subdivisions).

"Universality" in critical point systems is different from "universal principles" in mechanics, especially Newton's "law of universal gravitation." The Principle of Universality in critical point systems was first observed in 1895 by Pierre Curie who noted parallels between results obtained in his experiments with magnets and earlier published results of experiments with carbon dioxide. The Principle of Universality is, at root, a factual principle and each particular material medium must be individually considered — in contrast to the *a priori* universal sovereignty of Newton's law.

Even so, mathematical physics (statistical mechanics) suggests that, like Newton's laws (and Einstein's General Theory), critical point Principles are inherent in the nature of space and time. Critical point Principles require bodies for realization and the bodies vary; but the Principles stand separate from and above all bodies.

Critical point activity appears to require nothing more than a larger, heterogeneous body constituted by many uniform smaller bodies which interact according to a nearest-neighbor relationship that generates multiple phases in a temperature range. Critical point activity is not limited to such a body but such bodies are easiest to investigate. In other words, for any body so constituted, specific conditions can be found where the body will behave according to critical point Principles; but the range of conditions that support the Principles is exceedingly narrow. One such body is an idealized mathematical construction, the ***Ising Model***, discussed below. Activity in the Ising Model is driven by mechanisms and chance, with no consciousness or freedom. Universal critical point activity is present in the Ising Model and the nature of critical point activity is clarified by the mechanical basis, which has led to many investigations.

In a biological brain, there are bodies, called neuronal groups, that are constituted by biological cells called neurons; and this arrangement corresponds to the larger and smaller bodies in critical point systems. As a larger body, a neuronal group is made up of hundreds or thousands of units that are "the same," where each unit is a neuron or a specific assembly of several different neurons. Units interact via nearest-neighbor relations based in axonic projections and synapses. That is, a projection – an axon – extends from a neuron and makes contact – through synapses –

with numerous neighboring neurons. Each neuron produces pulses and a neuronal group can produce a repertoire of pulse patterns. In proposed models, a neuronal group selects a specific pulse pattern from its repertoire and maintains that pulse pattern during the specific phasic period of a cycle ("A" in § 7(a)).

Describing activity on a higher level of complexity: A neuronal group participates in collective activity when it passes through the critical point in synchronization with other neuronal groups, which are connected to it, as part of a structure of neuronal groups.

The Principle of Universality suggests that critical point Principles seen in inert material bodies will apply to an activated, engineered embodiment using Quad Nets. Quad Net designs show how such Principles might be realized in biological brains. I suggest that Universality applies notwithstanding important differences between activated Quad Nets and inert particles of matter in material bodies.

Magnets have been chosen as the vehicle for the presentation because of their simplicity (H_2O, for example, has a critical pressure as well as a critical temperature) and because of a close connection between iron magnets and the mathematical Ising Model of magnetism that is a foundation of Quad Net constructions. Yes, "brains are like iron magnets at the critical point," but, in addition, "brains are like water/steam at the critical point" and "brains are like brass at the critical point." More important, for development of Quad Nets, "brains are like the Ising Model at the critical point." The critical point and its Principles stand over and above any material embodiment.

c. Critical Moments in the Ising Model and in Freedom

A chief advantage of the Ising Model is that its behavior is grasped visually. Although the Ising Model is a mathematical model, you don't need mathematics to follow the course of activity. It unfolds in front of your eyes during online presentations, such as those accessed through web links given below.

To introduce the presentations, please note that there are important differences between the Ising Model and my applications to brain models. Research in the Ising Model is chiefly concerned with the situation where there is "0 external field." This is a situation that would be comparable to one where there are "no influences" on a person's decisions. Of course, in my approach the opposite it true, there are always influences (§ 6). Some online demonstrations allow for imposition of an external field.

A more profound and important difference is that the Ising Model is made up of passive elements; and each elements depends on a few quantities. In contrast, each element in a Quad Net device is an energy-conversion device that has a stream of energy flowing through it. The stream of energy flowing into each element is constant and the same for all. Likewise, I suppose that each neuron is nourished by a uniform, constant stream of sugar in the blood. In contrast to steady energy inflow, energy discharges occur in waves. Two or more different waves can be produced and multiple possibilities must be reduced to one actual production.

A final difference is that my approach involves cycling while traditional Ising Model researches typically focus on states where T is held at a fixed value.

There are various online presentations of the Ising Model that use Java applets, including:

http://bartok.ucsc.edu/peter/java/ising/keep/ising.html

http://www.ibiblio.org/e-notes/Perc/ising640.htm

http://www.phy.syr.edu/courses/ijmp_c/Ising.html

http://www2.truman.edu/~velasco/ising.html

See also
http://www.lassp.cornell.edu/sethna/Coarsening/What_Is_Coarsening.html

(Please advise of broken links.)

There are also more elaborate packages available for download and installation on various computer platforms.

You should experiment with versions of the Ising Model so that what follows is clear. I suggest that there is something universal going on, applicable to physical systems and psychological systems, to a single homogeneous body like a magnet or Quad Net device part and to complex heterogeneous bodies like a brain; and to both a single organism and also to a population of persons.

The Ising Model is embodied in a quadrille tiled array of elements, with the number of elements typically equal to n^2 (n x n). Each element has a spin that is either north or south. The number of elements that have a north spin minus the number of elements that have a south spin is defined as the ***net north magnetization***, if that number is greater than 0. A similar definition holds for the ***net south magnetization***, except that the number of south elements is greater than the number of north elements. For example, suppose there are 10,000 elements, that 8,000 are north and that 2,000 are south. There is a net north magnetization of 6,000. This magnetization corresponds to a description of the strength of bar magnets in terms of thumbtacks. Suppose that a magnet based on the Ising Model holds thumbtack for every 100 elements in the net north magnetization, or, symmetrically, the net south magnetization. With a net north magnetization of 6,000, the magnet can hold 60 thumbtacks.

Because of symmetry, any statement that is true about net north magnetization is equivalently true about net south magnetization. The Model can have either a net north magnetization or a net south magnetization but not both at once. If a Model has neither a net north magnetization nor a net south magnetization — e.g., the difference between the number of north elements and the number of south elements is small or fluctuating near 0 — it is ***unmagnetized***.

In the Ising Model, elements are continually flipping from north to south and from south to north; and any net magnetization will be undergoing continual changes. For each fixed temperature other than T_c, there is an ***equilibrium condition*** where the ***net magnetization is approximately constant in time***, although “wobbling” near the constant value. Such an equilibrium net magnetization is determined entirely by the temperature and not at all by the history of prior conditions. The net magnetization can be north or south, symmetrically. Figures 2a and 2b show the dependence of equilibrium net magnetization on temperature.

The conditions of the Ising Model are based on the interplay between two internal influences, an ***aligning influence*** and a ***disruptive influence***. The aligning influence acts between any element in the Ising Model and each of its nearest-neighbors. That is, there is a mechanism that tends to cause any two nearest-neighbors to be aligned; I pass over the details. In the absence of disruption, it is presumed that there is total alignment: an equilibrium condition is either all north or all south. The aligning influence does not depend on temperature.

The disruptive influence flips an element, randomly selected, from a present polarity to the opposite polarity, i.e., from north to south or from south to north. The hotter the temperature, the more frequent the flips. The disruptive influence is independent of the alignment of an element and is also independent of clustering of aligned elements.

Another important influence is an ***external field***, where one is present. Using the system shown in Image 1, the external field corresponds to an external magnet. Typically, in online systems, however, there is no external field.

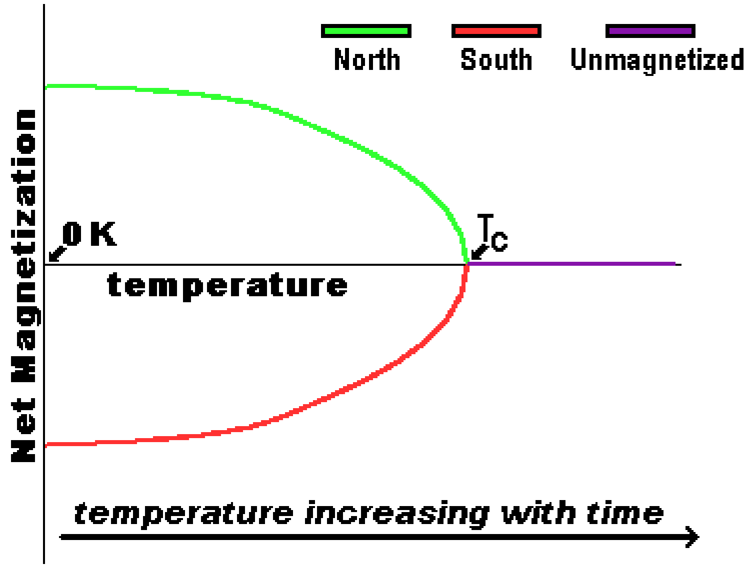
For closer examination, suppose that there is no external field, that the temperature of the Ising Model is ½ T_c, that there is a large equilibrium net north magnetization and that we are observing a cluster of elements that all have north spins. Then suppose that the disruptive influence flips one element in the center of the cluster to south, making it a ***delinquent*** element. Absent other disruptions, the surrounding elements exert an aligning influence and bring the delinquent element back into north alignment. If the system becomes hotter while still below T_c, there may be additional disruptions and additional delinquents that align with the original delinquent, so as to form a cluster of delinquents. A cluster of delinquents has its own aligning influence but it cannot stand against the surrounding matrix. The surrounding matrix will gradually impose re-alignments, from the outside in. The surrounding matrix can establish dominance so long as the temperature remains below the critical temperature; however, the relative loss of overall alignment gets larger as the critical temperature is approached and the net magnetization decreases.

As the temperature passes upward through T_c, disruptions occur so frequently that overall alignment is lost. Clusters intermingle and no memory is retained. The number of north spins and the number of south spins are approximately equal. There is no net magnetization and the material is unmagnetized. This condition is always the case when $T>T_c$.

Using an online demonstration that has a variable temperature and adjustable initial conditions, you can start at T=0 K (absolute zero) and set all the elements to one polarity. If you then raise the temperature but never go above the critical temperature, the initial polarity will sustain itself notwithstanding disruptions and delinquencies.

In Image 2a, the equilibrium net magnetization changes as temperature rises. The upper north (green) branch and the lower south (red) branch are equivalent but with opposite polarities. As the temperature starts rising from 0 K (Absolute Zero), the net magnetization slowly decreases. There is continuing decrease; and as the temperature reaches the critical point, the net magnetization plunges to 0. When $T>T_c$, the condition is unmagnetized.

Image 2a: Ising Model, temperature increasing with time

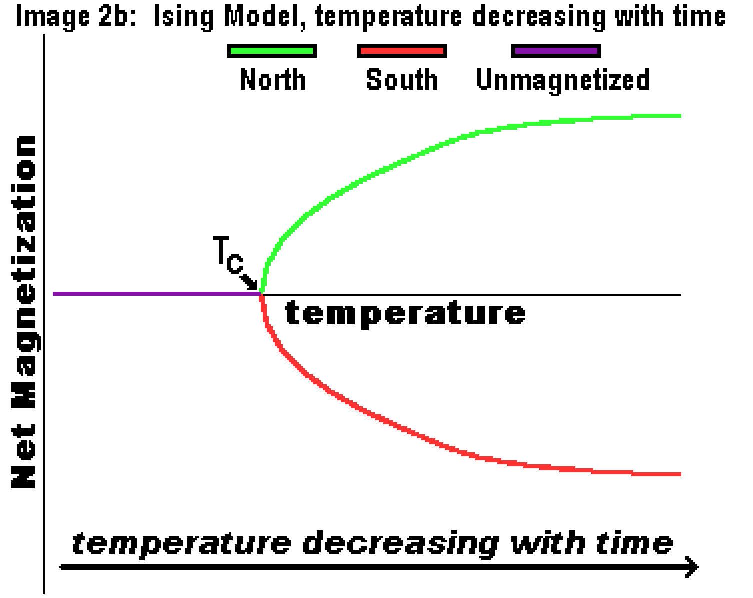


Finally, the most important part of the cycle occurs when T is decreased from $T>T_c$ to $T<T_c$. This is the ***quench***. The overarching principle of the Ising Model is that, when T is decreased from above T_c to below T_c and held at the new temperature, the condition of the Model will ***eventually*** change into an aligned matrix, with either net north magnetization or net south magnetization, plus randomly appearing delinquents. "Eventually" can, however, be elastic and can even extend to "never." In the latter case, we speak of a "frozen-in defect." Frozen-in defects are most likely to occur when the external field is near to 0. Typical frozen-in defects in the Ising Model are made up of co-existing bands of north spins and south spins. Such defects raise the net magnetization to a value greater than the equilibrium value.

Playing with online Ising Model demonstrations shows how to perform quenches in different ways that consistently lead to specific results. For example, a very fast quench from a very hot temperature (much greater than T_c) to a temperature near to 0 K will "freeze in" defects that never "dissolve." That is, equilibrium will never be reached. On the other hand, a slow quench is conducive to achieving equilibrium conditions at each step and can lead to the slow but inexorable dominance of one polarity. In the absence of a field, however, reaching a fully aligned condition as T approaches 0 K may require manipulations.

[Similar phenomena are seen in metallurgy. When steel is above a certain "transformation temperature" (727 ºC or 1341 ºF is a useful benchmark), the material is called "austenite." When the temperature is lowered beneath the transformation temperature, the final condition of the material depends on the quench, e.g., "martensite" (strong but brittle) upon a quick quench or "ferrite/pearlite" (softer and more malleable) upon a slow quench. With some alloys, cycling the material up to near its transformation temperature changes the properties.]

Image 2b shows what happens during a slow quench in an Ising Model. The cycle begins with $T>T_c$. The condition of the Model is unmagnetized. As time proceeds, the temperature decreases. As the temperature passes through T_c in the downward direction, either a north phase or a south phase becomes predominant. Note that the traces in Image 2b are mirror images of those in Image 2a.



Next consider a psychological counterpart of the course of events shown in Image 2b, namely the activity of an automobile driver waiting at a traffic signal. As discussed above in § 2(e), there are two possible deeds, “stop on red” and “go on green.” Assign the act “go” to the green branch in Image 2b and assign the act “stop” to the red branch. “Go” means, basically, stepping on the accelerator with the right foot. “Stop” likewise means stepping on the brake with the right foot.

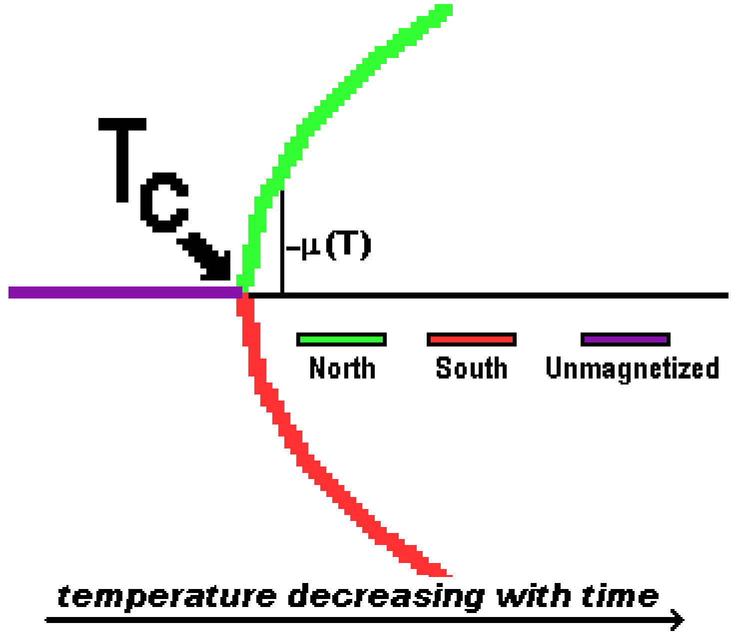
I suggest that, in a human being, there is a system that cyclically passes through its critical point like the magnet in Image 2b. As the system passes through the critical point, it can generate either a “go” activity pattern or a “stop” activity pattern. The pattern so generated will continue during the specific phasic period (A) of the cycle. The person waiting in his or her automobile has very few selections to make and may be ready for this one each time it comes around, perhaps several times a second, if the person is paying attention. A person must be conscious to respond to the traffic signal.

In sum, as selection occurs cyclically, observation of a red traffic signal will trigger the stop activity pattern and observation of a green traffic will trigger the go activity pattern.

If there were no traffic signal, there would be no selective influence as the system passes through the critical point and the person might have to exercise freedom, e.g., by initiating a survey of the roads leading into the intersection for approaching vehicles. Here, the traffic signal determines the selection. The fact that the traffic signal is a very small influence does not affect its capacity to determine the selection. At the critical point, even a tiny influence can determine the selection. In magnets and the Ising Model, in its ideal form, this capacity is called the ***infinite initial susceptibility***. A magnet passing through the critical point is so susceptible to the influence of another magnet that the magnetization of a very big magnet can be determined as it passes through the critical point by a very tiny influencing magnet or by a very tiny imbalance in opposing influences.

Image 3 is an enlarged view of the central part of Image 2b, with a more refined definition of the magnetization function, μ(T). That, is, for every temperature $T_i < T_c$, there is an equilibrium magnetization $\mu_i=\mu(T_i)$. The magnetization μ_i has the same strength at a given T_i regardless of whether the polarity is north or south.

Image 3: Dependence of magnetization on temperature



The value of μ measures the jump from a net north magnetization to an equivalent net south magnetization. Suppose there are 10,000 elements and 8,000 are north and 2,000 are south. The strength of μ is 6,000 with a net north magnetization. To change to an equivalent net south magnetization requires flipping 6,000 elements in a controlled way.

The critical moment for μ occurs as T goes down through T_c. When T is above T_c, the condition is unmagnetized. Numbers of north and south elements are about equal and μ is about equal to 0. The magnetization μ measures how difficult it is to turn, or convert, one possibility into the other. When the magnetization is near 0, that is, when T is near the critical point, clusters are transient. Below the critical point, phases are distinct. Interconversion that is easy when μ=0 becomes increasingly more difficult as μ increases. The critical point marks the unique coincidence of phasic separation and easy interconversion. As the system passes through the critical point, phases are just barely beginning to become distinct and interconversion occurs easily.

In sum, as T passes through T_c during a slow quench and as T continues to decrease, both polarities appear in fragmentary form and then one or the other predominates and increases to close to its maximum strength, relatively quickly at first and then more slowly.

The "quench" and the emergence of phases in the Ising Model suggest how experiences arise in a person. The suggestion can be stated mathematically. I suppose that there is a quantity that describes the condition of a brain part — call it ζ — that that is like μ in magnets and that is the basis for an experience that is specific to the brain part, e.g., a color, a sound or a sensation arising from muscular action. Similarly, all Quad Net device parts have an operational quantity similar to μ or ζ. [An operational quantity in a Quad Net device part is a timing interval, related to the pulse period of a neuron-like device – see *Timing Devices*.]
In brains, I suppose that each experience is based in one or more brain parts and that the intensity of an experience is based on different values of ζ in the various brain part or parts.

Like μ, ζ has a variation based on a control variable; the control variable is T in the Ising Model and ε in Quad Net devices. During cyclical activity in the brain part, there is a nonphasic period, the B in ABCABCABC. Psychologically, there is an experience of readiness or waiting. During the cycle, the control variable in a brain part passes through the critical point. Like in magnets where T passes downward through T_c and a polarity is established, and like in Quad Nets where ε passes downward though 0 and a particular wave phase is generated and maintained, so, I suggest, an experience is generated in a brain part that identifies the selection. The ***intensity*** of the experience is proportional to the rate of change of ζ, formally, $d\zeta/dt$. When ζ changes rapidly near the critical point, like μ, the intensity is strong. As ζ approaches its constant value, the intensity fades. The universal shape of a phase curve like that in Image 2, which plunges to 0 as the temperature rises past the critical point, means that all experiences arise in a similar way. A selection that is performed quickly produces a more intense experience at the moment of selection than one that is performed slowly. The relations establish a psychological correlation between fast, dramatic action, at one end of the range, and slow, quiet action at the other.

In other words, I suggest that each time an active brain part passes downward through the critical point, the brain part generates a pulsation of experience that is specific to that brain part. The experienced intensity of the pulsation depends on a rate that is controlled through timing of the cycle, which is coordinated with the timing cycles of other brain parts. Hence, the intensities of pulsations of experience vary across the brain in a way that depends on the coordination of cycles. I say that the individual pulsations gather into a ***texture*** of pulsations. Textures are shown musically by plucking the strings of musical instruments in an orchestra (a performance technique called *pizzicatto*) and, visually, by the pointillism of Impressionism. The experience of visual action can be based on momentary still photographs of a cinema film. In muscular action, a similar texture is constituted by the twitchings of muscle fibers.

Supported by Principles of Universality and Resemblances, Image 3 suggests a model for a person's exercise of freedom discussed in §§ 1-3 during which multiple possibilities turn into a single actuality. The following paragraph applies directly and in the same way, to magnets, to Quad Nets, to brain models and to exercises of freedom. I suggest that the paragraph states a universal form, applicable to different scales of space and time and to different scales of activity, ranging, e.g., from a single muscular move to a voluntary job change to an election.

At the critical point, phases co-exist, although other than at the critical point, the existence of any phase tends to exclude the existence of other phases. At the critical point, phases interconvert and conversions are reversible. There is an inherent balance between phases based on symmetry. Momentary imbalances generate impulses but no impulse can reach phasic dominance and each imbalance reverts to balance. As the cycle proceeds past the critical point, the balancing fails; and one particular impulse does reach phasic dominance, that is thereafter imposed. Typically, the selection is in accordance with external influences. At the critical point, phasic dominance is impossible; but, as the cycle proceeds, phasic dominance becomes inevitable - just as the selection is being made. The selected phase remains dominant until silenced by cycling. All activity begins with and ends with silence; the selection emerges from silence; and the selected phase fades into silence, in preparation for a fresh selection.

8. Organizing Critical Moments of Selection: a Person Exercising Freedom

a. Structural Overview

Previous sections have focused on the internal conditions of a single homogeneous body passing through a critical moment, with the Ising Model as the center of the focus. Principles of Universality and Resemblances were introduced to suggest extensions of the model to more complex systems involving multiple connected bodies. This section discusses more complex systems in greater detail and shows how the extensions might be realized. While the previous sections chiefly previewed Part Two (Principles of Selectional Freedom), this section chiefly previews Part Three (Principles of Organizational Freedom). On the largest scale, I suggest that a brain serves as the ***dwelling*** of a person exercising freedom; and I suggest, through the model, how that might be possible. Dwelling arises from interacting, multiple cycles of selections.

On the largest scale, an entire brain is modeled by a global heterogeneous body made up of smaller bodies organized both by ***nesting*** and also by ***interconnections***. In the model, there is an ultimate decomposition of an entire brain into distinct neuronal groups (§ 5) in each of which neurons are uniformly connected, or homogeneous; but differences occur between groups. Each interconnection runs between two homogeneous neuronal groups.

Nesting is a universal principle of construction. In nesting, a greater system contains other, lesser systems that resemble the greater system. The resemblance cannot be an identity because a system cannot contain itself. But resemblances between the greater system and the lesser system are more important than differences. For example, a lesser system, like a child, can grow into a greater system, like a parent, e.g., if child imitates the parent. Nesting can occur in space, in time and in activities (deeds). E.g., Quad Net constructions incorporate spatial nesting; cycles within cycles establish temporal nesting; and habits, routines, instructions, customs and practices organize nested deeds.

A body that has its own character is also characterized by interconnections with other bodies. Quad Nets suggests an approach to interconnections between neuronal groups. Allowing for free deformation in the manner of topology, the bodily surfaces of two interconnected neuronal groups are each made up of many thousands of microscopic facing surfaces inside synapses formed between neurons in the two groups. A synapse is formed where an axon projected from a neuron in one group terminates onto a neuron of the other group and there is a synaptic cleft or gap between the facing surfaces in which one-way interactivity occurs. Neuronal groups interact through such collective bodily surfaces.

During engagement with particular aspects of reality — when the person or organism is in a particular situation — a number of distinct bodies and interconnections work together and make up an ***active system***. ***Activation*** means that that the bodies and interconnections in the active system are consuming energy at an elevated level, compared to consumption when not activated. E.g., during sensory-motor activity activated sensory and motor systems consume a greater share of energy. Only activated systems pass through the critical point. The organism's activities may also involve bodies that are cycling but where activities do not pass through the critical point.

Generally, I suppose that when brain parts are operating but not passing through the critical point, the resulting courses of action are unconscious. The level of activation may also be minimal. E.g., while walking on a path in a park with a companion, engaged in conversation, I am observe offensive litter on the path and avoid it without missing a word.

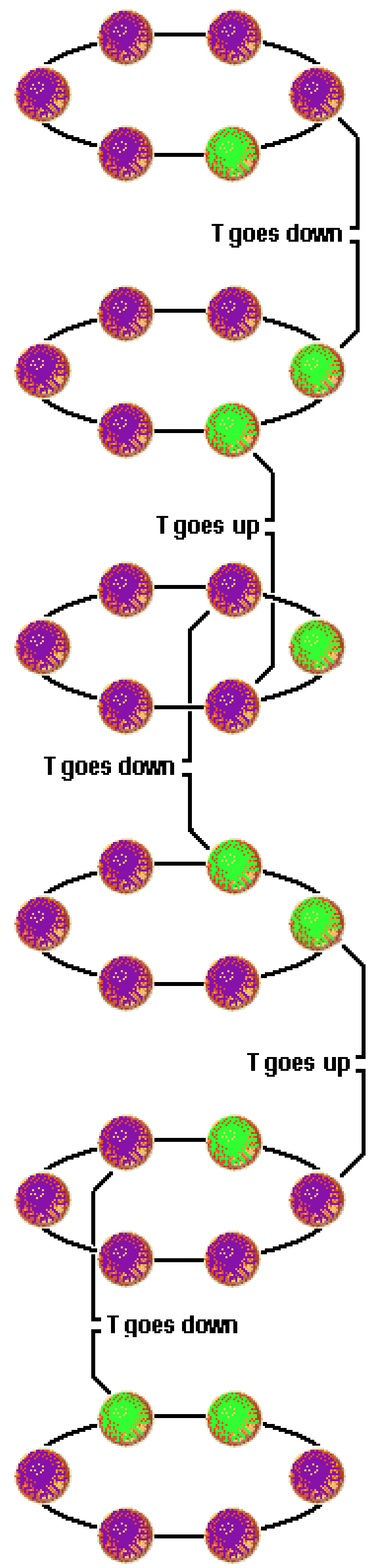
Not all interconnections between activated bodies will be activated during engagement with a particular situation; rather, activation of interconnections is only partial and is specific to the situation. That is, a situation is a limited aspect of reality that results in the activation of some bodies and interconnections, but only a fraction of the bodies and interconnections, in the brain of a person or other organism. The activation defines the ***active structure*** of the bodies and interconnections involved in the activity of the brain or brain model.

The make-up of active systems in a person's brain are variable, changing, e.g., from working in an office to driving home in crowded city traffic to dining with the family to attending a concert. The clearest view is obtained when an organism engages reality such that the activated structure in its brain remains fixed in time, e.g., a worker at a work station; this is a ***fixed situation***.

b. Operational organization: sequencing and circularity

I suggest that a critical point condition can be sustained by circulating a phase in a structure of bodies that successively pass through the critical point. E.g., as shown in Image 4, suppose six magnets are arranged in a circle so that each can influence and be influenced by two nearest neighbors. If the temperature of a magnet passes down through the critical point, the magnet will be influenced by the magnetization of a neighbor. If a neighbor is unmagnetized, there is no influence.

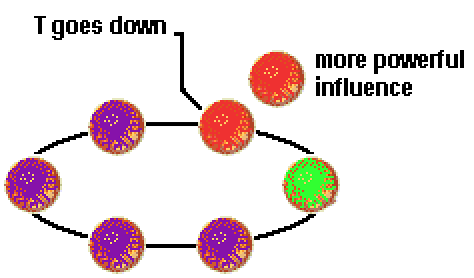
Image 4: Phase Circulation



In Image 4, the temperatures in the magnets in the circle successively cycle down through the critical point and then up above the critical point, transferring a north phase around the circle. A ***cooling wave*** travels counter-clockwise with a ***heating wave*** following a step-and-a-half later. Likewise, Quad Net device parts can be connected into a circularity structure using Phase Transfer Controllers.

In larger-scale constructions with many parts, an activity pattern (a particular phase) is passed from part to part, around a circularity, while shaped by various influences. Such shaping is shown in Image 5, showing a modification of the fourth stage of Image 4, where the more powerful influence changes the phase from north to south,

Image 5: Phase modification during circulation



I suggest that sustained circulation of a phase, subject to ongoing modification, is the defining characteristic of deliberation during many exercises of freedom, such as freedom exercised by Mom in the market and by the Judge. Through such circulations, selections can ***dwell*** in a brain or brain model. In a further stage of developments, I suggest that multiple circulating selections can dwell in different structures of brain parts and interact with one another, leading to variations in actual results of selections.

[Unfinished draft 08/08/07]