How to solve “free will” puzzles and overcome limitations of platonic science

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Summary

“Free will” puzzles are failed attempts to make freedom fit into forms of science. The failures seem puzzling because of widespread beliefs that forms of science describe and control everything. Errors in such beliefs are shown by reconstruction of forms of “platonic science” that were invented in ancient Greece and that have developed into modern physics. Like Plato’s Ideas, modern Laws of Physics are said to exercise hegemonic control by means of universal and invariant principles. Linear forms and rigid symmetries are abstracted from geometry and indifference. Processes tied to equilibrium require static surroundings and confine changes to continuous increments. Such forms, based on empty space, fail to describe actual material transformations that occur during the making of steel or the production of snowflakes. They also fail to describe muscular movements and related bodily feelings of persons and other animals that have actual life. Limitations of platonic science are overcome by means of new forms with the character of time, beginning with “beats” and saccadic, jumpy forms. Technologies of action and freedom generate and control such temporal forms in proposed device models of muscles and brains. Development leads to episodic balancing forms, which pass through critical moments of transformation, resembling those that occur when persons exercise freedom, e.g., during a moment of overtaking in a footrace or during a moment of decision by a courtroom jury.

Condensed outline

1. Muscular movements of actual life lead to a new approach to freedom.
2. Nietzsche’s “will to power” shows the defects of metaphysical constructions that fail to connect to actual life.
3. In metaphysical constructions that were developed by ancient Greeks as part of “platonic science,” an imaginary domain is occupied by mental objects called “Ideas” that are impersonal and eternal, that have the rigid symmetries of geometrical space and that are supposed to control actual lives of persons.
4. Modern versions of platonic science construct imaginary domains in which particles, objects, events and changes are controlled by eternal, universal Laws of Physics. Such Laws would impose rigid symmetries of empty space on material bodies; but they fail to describe or control actual transformational changes that occur during a fast quench of red-hot steel or during the growth of crystalline snowflakes in a cloud of water vapor.
5. Modern cognitive psychology and brain science derogate muscular movements and related bodily feelings of actual life; instead, depersonalized information is supposed to be processed according to forms of computation based on principles of platonic science.
6. In new alternative constructions, “beats” of actual life, along with wags of a Dogtail, are modeled by movements of muscle-like modules. Temporal forms based on such movements include episodic balancing forms that are embodied in new technologies as Shimmering Sensitivity, a principle of freedom, and that also control sports competitions and jury trials. Outcomes of such contests often turn on personal efforts and personal decisions that occur during transformational critical moments.

Detailed Outline

1. Muscular movements of actual life lead to a new approach to freedom.
    a. "Free will" puzzles are different from freedom in actual life.
    b. Actual life begins with infantile repetition of muscular movements.
    c. Repetition develops into invariance principles and metaphysical constructions.
    d. In contrast to empty concepts of "will" and "free will," physical science and technology have successfully applied metaphysical constructions to actual life.

2. Nietzsche's "will to power" shows the defects of metaphysical constructions that fail to connect to actual life.

3. In metaphysical constructions that were developed by ancient Greeks as part of "platonic science," an imaginary domain is occupied by mental objects called "Ideas" that are impersonal and eternal, that have the rigid symmetries of geometrical space and that are supposed to control actual lives of persons.
    a. Hegemonies in platonic constructions.
    b. Hegemony of impersonal invariance in metaphysical domains.
    c. "Principle of sufficient reason" imposes eternal symmetries and indifference.
    d. Platonic constructions have the rigid character of geometrical space.

4. Modern versions of platonic science construct imaginary domains in which particles, objects, events and changes are controlled by eternal, universal Laws of Physics. Such Laws would impose rigid symmetries of empty space on material bodies; but they fail to describe or control actual transformational changes that occur during a fast quench of red-hot steel or during the growth of crystalline snowflakes in a cloud of water vapor.
    a. Modern platonic physics has advocates and alternatives.
    b. Minkowski's "union of space and time" illustrates puzzling claims of conceptual hegemony that disregard the character of time in actual life.
    c. Reconstructing time into a kind of space makes time fit the primal linear form of platonic science.
    d. Classical thermodynamics is based on equilibrium that excludes multiple possibilities, that imposes continuity and that leads to linear forms.
    e. Quasi-static linearized forms effectively describe some slow transformations, e.g., formation of pearlite in steel-making; but such forms fail to describe similar faster transformations, e.g., formation of martensite during a fast quench of red-hot steel.
    f. Laws of Physics fail to describe or control discontinuous transformations of water vapor into individual crystalline snowflakes.

5. Modern cognitive psychology and brain science derogate muscular movements and related bodily feelings of actual life; instead, depersonalized information is supposed to be processed according to forms of computation based on principles of platonic science.

    a. The alternative approach provides a view of brain operations in which muscular movements have foundational importance.

    b. Although William James recognized issues of muscular movements and related bodily feelings, he made bodily feelings into sensory inputs leading to a centralized system which generates muscular movements as outputs.

    c. Even more than James, modern cognitive psychology views human beings as depersonalized processors of information, with action as an abstract final result.

    d. Models of psychology and brains aiming at computers lead to electronics designs that embody platonic principles of linearity, equilibrium and energy conservation and that fail to connect to actual life.

6. In new alternative constructions, "beats" of actual life, along with wags of a Dogtail, are modeled by movements of muscle-like modules. Temporal forms based on such movements include episodic balancing forms that are embodied in new technologies as Shimmering Sensitivity, a principle of freedom, and that also control sports competitions and jury trials. Outcomes of such contests often turn on personal efforts and personal decisions that occur during transformational critical moments.

    a. ***The beat*** is a primal temporal form in new models of actual life.

    b. A beat dwells in muscle-like activity in proposed new technologies.

    c. "A Dogtail for Wagging" is a timing device design for production of classes of muscle-like movements, including positioning movements, kicking movements and wagging movements controlled by a beat.

    d. Forms of platonic science do not connect to, control or describe wagging movements of the Dogtail for Wagging.

    e. Classes of muscle-like movements of the Dogtail correspond to activations that generate temporal forms in new technologies. Constructions lead to episodic balancing forms, where symmetry between possible outcomes is established at the start; then symmetry changes to asymmetry as two or more possible outcomes change into one actual outcome. Proposed Quad Net devices embody episodic balancing forms in transformational processes of Shimmering Sensitivity.

    f. Sports competitions and civil trials illustrate adaptations of strife to episodic forms of balancing. Such contests lead to transformational critical moments, e.g., moments of overtaking during footraces and moments of decision by judges and juries in courtroom proceedings.

1. Muscular movements of actual life lead to a new approach to freedom.

a. "Free-will" puzzles are different from freedom in actual life.

"Free will" is like a jigsaw puzzle where pieces do not fit together. Different possible futures, conscious decisions and physical mechanisms have not been unified by a "free will" that is consistent with personal experience. Free-will puzzles have an ancient heritage. In modern versions, scientists declare that Laws of Physics prohibit any possibility of "free will."

I suggest that free-will puzzles fail to connect to freedom in actual life. I suggest that misfits of free-will puzzles are the result of reliance on forms of science that originated in Ideas of Plato. Platonic science uses ***rigid forms*** based on ***space*** that do not fit the character of freedom. Critical review of platonic science leads to ***changing forms*** based on ***time*** that fit better.

In examples of sports competitions and musical performances, timing of actions is of high importance and temporal forms control extended exercises of freedom that occur while persons are producing "voluntary" muscular movements. Free-will puzzles, in contrast, lack the ***streams of muscular movements*** involved in such actual exercises of freedom. In the puzzles, persons under examination are put into static positions, bodily and mentally, with scant opportunities for action. Periods of passive waiting are punctuated by isolated events.

In a typical free-will puzzle situation, a "research subject" is led to a test station and instructed to sit and relax. Experimenters attach devices to the subject's head and arm. While immobile, the subject is instructed to press a button "spontaneously." Attached devices show that neuronal activity leading towards muscular movement starts before the subject is aware of it. Such an investigation into awareness involves no more than an isolated quantum of freedom. Any will is that of the experimenters. Some free-will puzzles even include brain surgery on a subject who has been bound to a table. Invisibility of freedom or "free will" is inherent in such situations.

A counter-example is based on streams of muscular movements. Suppose that you are walking steadily on a level, otherwise vacant sidewalk. While walking, you maintain awareness of feelings based in your body and in movements of its parts – your feet, legs, buttocks, hips, back, arms, etc. In other words, you experience "images" of your body parts and of their movements. Using such imagery, you can consciously vary your pace (step rate), stride (step length) and style of walking (e.g., stiff or loose). Such variations of movement are exercises of freedom performed with consciousness. Your body must be moving for you to exercise such freedom.

Psychological terms "feelings" and "awareness" are centered closely around the ***focal present moment of now***. My constructions of "imagery" and "images" begin with images of bodily feelings and "now body-imagery." "Consciousness" and "experience" have more complex characters that grow out of present momentary awareness and that include forms and plans.

Often we walk without awareness of the body or of its feelings. Awareness adds to activity that occurs at first without awareness. Exercises of freedom occur while a person walks regardless of whether awareness is present. For example, two friends walk side-by-side on a crowded sidewalk while holding packages and absorbed in conversation; they exercise freedom without awareness by adjusting pace, stride and style of walking to stay close together. Such freedom is chiefly exercised around the pelvis, while hands, mouth and mind are engaged in other activities.

A person walking on a sidewalk does not need "free will" to keep moving. No psychological function says "step, step, step." ***The body moves on its own and exercises freedom on its own***, whether or not we are aware of it. Movements and freedom are prior to consciousness or will.

In brief, human bodies are moving on their own all the time, e.g., during sleep. Movements are accompanied by variable levels of awareness and many daily actions lack heightened awareness. When people sit together, e.g., in a classroom, a "subconscious self" is in control of many bodies and body parts, causing them to fidget, scratch and jiggle. On the other hand, as shown by skilled performers, persons use consciousness to invent new movements.

A person walking on a sidewalk may consciously follow a particular route. Other times, the person may follow a habitual route and walk in an "unconscious" fashion. "How to step off the curb" and "which way at the intersection" are decided on each distinct occasion, whether consciously or unconsciously. Regardless of consciousness, the person actually exercises freedom. Suppose that the planned destination of a trip slips from a person's mind and the person takes a habitual route that goes somewhere else. On such an occasion, the person exercises freedom unconsciously. If the person goes to the planned destination, freedom is exercised consciously. Freedom originates in movement and in opportunities for choice, not in consciousness. While the body is moving, it is free. Consciousness and images, e.g., images in maps, can enlarge freedom but the primal source is muscular. A walking person can exercise freedom without a map and without a plan.

Similarly, a person driving a motor vehicle in traffic is not puzzled about "free will." Motorists are continually exercising freedom by pressing on the accelerator and the brake and by turning the steering wheel. Sudden muscular movements – e.g., slamming on the brakes – sometimes occur before a motorist is aware of them. Exercises of freedom occur in response to changing circumstances and unforeseen events. Negligence or error can have serious consequences. Collectively, choices make up a course of action and construct a trip that has been traveled. Some motorists initiate action frequently, seeking opportunities to complete the trip quickly; other motorists prefer a safer, slower, smoother ride with a lesser stream of activity. Sudden recollection of a scheduled engagement may change a relaxed trip into one made tense by hurry.

Question about "free will" do not trouble athletes engaged in a sports competition. As discussed below, sports arenas are places to exercise freedom; and teams and players are all determined to ***win***. Training enables them to take advantage of opportunities that could not have been planned.

Musicians performing in front of an audience are not focused on concerns about "free will." They have devoted hours of practice and rehearsal concentrating on their muscular movements and on the sounds that the movements are making. Jazz musicians sometimes get to improvise during a performance. But a musician must learn the piece before attempting improvisation.

In sum, free-will puzzles do not detract from freedom exercised by pedestrians, motorists, athletes and musicians — whose bodies are producing muscular movements of actual life. The puzzles appear to be inconsequential as well as fallacious. They do, however, lead to more serious questions; and a full analysis shows new ways to approach weightier endeavors.

This essay presents an alternative approach to questions about freedom. My approach does not invoke "universal and invariant principles" that supposedly describe and control events. Instead, such "platonism" is intentionally avoided. I suggest that important changes in material bodies – e.g., changes in bodies of water, steel, muscles, brains and persons – have ***individual characters*** that cannot be satisfactorily described or controlled by such platonic principles. The diverse shapes of snowflakes provide a focal example. Similarly, unique changes in a person's brains partially encode memories of external events, where features can only be selectively detected.

Developmental goals of this essay include applications of new principles to institutions, e.g., for use in courts. One form of activity in such institutional settings is a ***contest***, such as a contest between plaintiff and defendant in a civil lawsuit. Other contests include sports competitions put on by educational institutions. A chief feature of contests is use of ***episodic balancing forms***. Such forms provide opportunities for exercises of freedom by contestants in sports competitions. Judges and juries similarly exercise freedom when they use episodic balancing forms to decide civil trials. Outcomes of such contests can turn on individual character or personal performance.

An ***episode*** is a course of action that has a starting time and a finishing time, at least in retrospect. Songs and games are episodes. The action content of an episode occurs between the starting time and the finishing time. A later episode can resemble a prior episode. In other words, some episodes repeat, more or less. Features of later episodes can be "the same" as those in a prior episode or "different from" those in prior episodes. "Same and different" are discussed below in connection with "matching operations." Repeating episodes occur in diverse activities and provide chief subject matters for my investigations.

In an episodic balancing form, e.g., in a contest, action starts with two or more participants in positions that are symmetrical. The form imposes symmetry as to important particulars at the starting time. Courtrooms and sports arenas give each contestant an "equal chance" at victory, or at least an appearance thereof. Equal chances are put "in balance" at the outset. By the end of a contest, however, the positions have become highly asymmetrical or unbalanced. There is a winner and loser(s) and the difference is a big one. During the episode, symmetry changes to asymmetry. Balance is initially established by constraint and then constraints are released. A period of competition ensues. When contestants are evenly matched, or nearly so, more than one outcome is possible. Each possible outcome is assigned to a distinct polarity. A change in symmetry or polarity (a change from balanced to unbalanced or from one leader to another) occurs during a ***critical moment***. Typically, a critical moment is a focus of importance in an episodic balancing form. Movements that occur during a critical moment can determine the outcome of a contest. Persons may exercise freedom during such a critical moment, e.g., jurors may exercise freedom during the critical moment when they are deliberating in the jury room.

Contests are occurrences of ***strife*** that have been domesticated through application of symmetry principles. Symmetrical features of episodic balancing forms are imposed on a contest situation through efforts of arena designers and game officials in sports competitions and through legal principles and judicial oversight in civil trials. In contrast, natural situations involving strife are not intentionally symmetrical. Rather, the dominant fighter will seek to enlarge any advantage.

Symmetry in court contests has clear social benefits. People who feel that they have been treated "fairly" in court are more likely to accept unfavorable judgments. "Fairness" requires an apparent absence of favor for certain persons or discrimination against certain persons, which is to say, treating all contestants "the same." Persons, e.g., siblings, have high sensitivities to signs of favor or discrimination. We know when we are not being treated "the same" as others.

I suggest that such symmetries and episodic balancing forms are products of our intelligence. That is, "fairness" and "critical moments" are features of brain operations that are projected and used in external activities. Freedom that occurs in contests is a reflection of freedom in brain operations. Freedom in brain operations is based on freedom arising from muscular movements.

New technologies (Quad Nets and timing devices) propose device models that generate and control critical moments during processes that follow episodic balancing forms. In ultimate designs, a complex system of devices drives muscle-like movements of an engineered organism.

Proposed Quad Net devices generate ***Shimmering Sensitivity***, a physical principle of freedom based on episodic balancing forms that I suggest is also generated during neuronal processes. The principle is discussed in § 6(d) below; http://www.quadnets.com/puzzle.html#SS offers another view. To sum up chief operating features: Quad Net devices generate Shimmering Sensitivity to perform ***processes of selection*** or choice.

I also suggest that Shimmering Sensitivity has a ***non-local reach***. In other words, a unified condition of Shimmering Sensitivity can extend over many devices simultaneously, or more exactly, by means of synchronized processes. Synchronized processes perform multiple selections together. The concept of "entrainment of ticking clocks" is useful as a starting point. That is, "identical" clocks will tick in synchronization with each other, or collectively. In anticipated designs, structures of selecting devices are activated and then organized in transient assemblies by Shimmering Sensitivity. In envisioned designs, Shimmering Sensitivity makes unified selections in a large-scale system of devices; cycling waves of critical moments are episodically entrained within a body of activity through operations that have non-local reach

Further, I suggest that Shimmering Sensitivity is a generator of imagery that resembles feelings. Imagery occurs in flickers that appear during critical moments and that correspond to focal moments of now. One stream of processes generates images based in neurons sensing activity in skin, muscles and joints; a separate stream of processes generates muscular movements; and separate streams of processes are synchronized and entrained during activities. Some movement selections are also guided by remote images on a higher level, e.g., matching movements to forms in memories or to plans. In sum, designs using Shimmering Sensitivity suggest a model of muscle-like movements that are guided by momentary images from multiple sources.

Bypassing technical details, which are set forth in other publications, there are situations in which simple Quad Net devices operate cyclically. Each cycle embodies an episodic balancing form. The cycle begins with a preparatory resting period. Then action starts and passes through a critical moment, performing the selection of one actual movement from two or more possible movements. In crude forms discussed here, the number of possible movements, the ***repertoire***, is small. Through non-local reach extending over many devices, I suggest that small repertoires in separate devices can combine to become a large collective repertoire.

Suppose that we enter a simple Quad Net (QN) cycle during the preparatory resting period. Thereafter, a critical moment starts and proceeds to completion, carrying out a selection. At the start of the critical moment, the process generates co-existing germinal fragments of signals for multiple possible movements, perhaps appearing as tentative impulses that are competing and shifting back and forth, a condition of "Shimmering." The device has a symmetrical field and multiple possibilities are initially balanced, like the symmetry and balancing that occur at the beginning of a contest. Balancing makes Shimmering possible. Thereafter, during the critical moment, and with Sensitivity to multiple influences, such as transient influences from external sources, ***multiple possible movements change into a single actual movement***. Such a change may require an exercise of freedom. The exercise of freedom may or may not involve awareness and may or may not be subject to conscious control. Similar occurrences in actual life include sorting vegetables or coins, making the next stroke in a ping-pong game or, at a party, picking up one dessert plate from a table holding several such plates.

Alternative principles of physics are behind alternative models of brains and psychology. My "constructivist materialism" is based on properties of material bodies that undergo sudden large-scale changes. For example, water vapor in a cloud freezes into snowflakes. In other words, a gas changes into ice crystals, a process called a ***phase change***. During a phase change, there is a complete change of form, a ***transformation***. A coherent but diffuse fluid becomes a set of fixed and disjoint solids. An enormous number of possible snowflake shapes turn into a relatively few actual shapes, just as, in the Quad Net model, multiple possible muscle-like movements turn into a single actual movement. ***Critical point phase changes***, a topic explored by physicists and engineers, is the basis of Shimmering Sensitivity and non-local reach.

Quad Net models provide an alternative point of view for free-will puzzles and the confusions they engender. I suggest that, in such puzzles, an extended process of selection is confused with a briefer moment of change. In the "free will" experiment described above, a selection process starts when the research subject is put into a relaxed condition and given instructions; the process achieves a climactic moment of change and actual movement only after further preparation.

Confusion is compounded by attempts to make imagery or consciousness into the cause of movement, e.g., saying that images cause movements. Such attempts neglect the facts that animal bodies move on their own, whether consciously or not, and that movements are subject to competing influences. Free-will puzzles attempt to frame the question "how do images cause action" in ways that fit scientific demands for causation, isolation and certainty. E.g.: "How do visual images of a banana on a tree cause a monkey to reach out and grab it?" As discussed below, William James invented a concept of "ideo-motor action" to explain such movements.

In my approach, ***itching and scratching*** is a primal but intelligent form of "ideo-motor action" that operates prior to awareness and that can develop into purposeful activity. Suppose that an itch appears; then, scratching it activates and locates – perhaps even "causes" – additional itches. More generally, images influence movements when an organism is moving or ready to move. To use causal concepts: movements, activations and readiness are primary or driving causes; feelings and images are secondary or selective causes. Animals look for food while they are eating or when they are hungry. Competing activations, feelings and movements, if triggered by other imagery, might cause the monkey to ignore bananas and reach for a mate. If a lion appears, still other activity is triggered. Small animals out in the wild are always ready to flee.

In alternative constructions, multiple layers of activity operate independently; they also interact in diverse ways, sometimes uniting, sometimes disjoint and sometimes clashing. Musical examples of layered constructions include soprano-alto-tenor-bass and background-drums-soloist. Layered constructions in actual life include meal preparation and dressing oneself with undergarments, social apparel and protection from the elements. In constructing a layered model of voluntary muscular movements, I locate the lowest layers of generators of movements and related feelings inside spinal vertebra and in dorsal root ganglia that appear as rows of "mini-brains" on both sides of the spine. I suggest that primal feelings are generated inside and around the spine during bodily movements regardless of and prior to any awareness of them, which may or may not occur. Such primal feelings guide muscular movements which occur on their own. Lower layers of neurons in and around the spine generate such images (feelings) in operations that may, at various times, occur either synchronously with or independently of operations in various parts of the central brain (e.g., cerebellum, cerebrum) that have more complex and extensive operations and that generate larger-scale imagery.

“Matching” is a pervasive principle in my constructions, appearing in device operations and signals, in muscular movements of animals and in imagery. Matching connects operations that occur in different layers; it also connects device operations with psychology. One meaning of “match” refers to actions that entrain or that occur synchronously, e.g., marching band. Another meaning of “match” is that of an engineer, who matches operational quantities, such as impedances, or who chooses the capacity of a device to meet anticipated demands. A third meaning invokes an equals sign. A fourth uses oppositional signals and movements to control balancing in symmetrized systems such as the Dogtail or bidding in poker. In like vein, I suggest that control signals generated in the central brain must “match” those generated in the spine.

In some image-matching operations, two images are detected to be “the same.” “The same” can operate on multiple levels and does not always mean “identical.” Distinguishing features can occur in images that are also “the same,” e.g., different performances of a particular song. Operations that match and distinguish images use various kind of processes and multiple processes. Some matching processes are exacting and others tolerate discrepancies. Some matches require consciousness, e.g., matching finger movements to musical notes in a score.

A layered catalogue of imagery starts with current “now” images of bodily feelings and movements. Layers of imagery add “now” sensory inputs (e.g., balances), sights (e.g., colors) and sounds (e.g., “no!” to a toddler) that can be combined with bodily feelings and movements. Sensory images can blend, like watercolors blend, or they generate new images, e.g., harmonies. Through progressive training and use of symbolic imagery, further control over movements can be established by means of written instructions. Among other functions, images encode and index selections for future matching; and imagery is remembered in “forms” that are suitable for matching. Anticipated Quad Net device designs maintain Shimmering Sensitivity processes that match now images to images reconstructed from memories and forms – e.g., mimicking conscious operations that “stop on red, go on green” at the traffic light.

Long-range goals for development of Quad Net systems include use of “forms” of imagery that have operational influence. However, such forms do not determine outcomes of processes of Shimmering Sensitivity. Devices are subject to multiple influences, including activation levels, ongoing muscle-like movements and external events. In anticipated projects, images influence selections through image-matching operations that involve Shimmering Sensitivity. Shimmering Sensitivity is immersed in influences but has an autonomous non-local character that extends in a continuously flickering body through layers of parts. Some layers may be generating conscious imagery while interacting parts in other layers make selections without generating imagery. During movements that require exercises of freedom, e.g., during sports competitions and musical performances, imagery participates in conscious selections that can partially control streams of muscular movements. But such streams also have independent sources, selections and controls based on individual character and training.

Applying such principles to actual life, a person can act under control of imagery or the person can act contrary to imagery, first repeating an earlier action and then doing something different, despite imagery that commands consistency. A person can follow a particular form or violate the form, e.g., walk across the street against the traffic light. In actual life, of course, most people habitually or intentionally base their actions on imagery and forms so that their actions are lawful, purposeful and rational. But possibilities of unlawful, irrational, distracted or self-damaging actions are not thereby excluded. In actual life, such actions occur frequently. If imagery causes behavior, why does it fail on such occasions?

b. Actual life begins with infantile repetition of muscular movements.

The alternative approach starts with principles of child psychology of Jean Piaget (1896-1980), who investigated development of human intelligence during infancy and childhood. I adapt Piaget's psychological principles for use as design principles in new technologies.

"Piaget has sometimes labeled his position *constructivism*, to capture the sense in which the child must make and remake the basic concepts and logical thought-forms that constitute his intelligence. Piaget prefers to say that the child is inventing rather than discovering his ideas. This distinction separates him both from empiricism and from apriorism. The ideas in question do not preexist out there in the world, only awaiting their discovery by the child; each child must invent them for himself. By the same token, since the ideas have no a priori external existence, they cannot be discovered by simple exposure; rather, they must be constructed or invented by the child. Thus, Piaget's book dealing with growth of concepts of object, space, time and causality in the first year of life is not called *The Discovery of Reality*, but *The Construction of Reality in the Child*." (Gruber and Vonèche at xxxviii-xxxix.)

This essay is a large-scale construction that contains smaller constructions, including models. Some models describe images (e.g., conscious experiences) and are called psychological models. Other models propose devices that are part of new technologies. Psychological models and device models are discussed in terms of common functions, e.g., balancing and matching.

I adapt Piaget's methods to construct classes of "psychological objects." This initial construction of objects illustrates my "layered construction" method and provides materials for later constructions. Initial layers in the object construction are made of (1) actual objects, (2) sensory objects and (3) mental objects. Such objects are grounded in personal experience that is presumptively shared by all intelligent persons. The objects are based on experience of: (1) ***muscular movements*** that are coordinated with feelings generated within a person's body (actual objects); (2) ***organs of sensation*** (e.g., skin, eyes and ears) and brain parts that generate and project images onto a "real world of things" that includes one's own body and other bodies (sensory objects); and (3) ***image constructions*** that incorporate such feelings, movements and things in relations and structures (mental objects). Each layer stands on and develops from lower layers. Each layer also has a specific individualized character. Here, muscular movements are foundational and all objects have origins in such movements and in related bodily feelings. The alternative approach differs from scientific approaches, where sensory objects are foundational. It originates in ***action*** (muscular movements) rather than from ***states*** (sensory observations).

In alternative constructions, forms o f muscular movements are points of origin for development of forms of thought, social interaction and institutional activity. Important forms include "following," "focusing" and "balancing."

As an example of the primacy of muscular movements, I suggest that the personal computer routine for "opening a data file" was originally based on muscular movements involved in "looking at a file folder in an office," namely, pulling open a file drawer, extracting a particular file folder from the file drawer and leafing through papers inside the file folder. Eye-hand movements controlling a keyboard or mouse follow a similar form where a "directory" in computer storage resembles a "file drawer" in an office and a "data file" resembles a "file folder." One "looking for a file folder in an office" performs an action of "focusing" during which attention is shifted from the file drawer as a whole to a particular file folder in the file drawer. On the computer, the person looking at the monitor similarly shifts attention from the directory to a particular file in the directory. In both situations, there may be a sequence of actions during which successive folder labels (or filenames) are repetitively “tested” or compared to an image in the person’s memory, until a successful “match” is made; then, the “matching” folder or file is extracted or opened. In computers, as in offices, resources are organized to deal with collections of items, such as filing cabinets filled with file folders and directories filled with files.

In alternative constructions, ***repetition*** of muscular movements is of primal importance. Even in the first reflexive behaviors of newborn infants, “there is a tendency toward repetition, or, in objective terms, cumulative repetition.” (Piaget, Origins of Intelligence, 33.) The first stage of a baby’s development beyond reflexes is called the “Primary Circular Reaction” – a phrase that describes actions that “are ordinarily called ‘acquired associations,’ habits or even conditioned reflexes.” “The repetition of the cycle which has been acquired or is in the process of being acquired is what J. M. Baldwin has called the ‘circular reaction.’ ” (47 - 49.)

Some reflexes thus become ***self-perpetuating***. Eventually, such reflexes will develop into bodies that move on their own and that exercise freedom on their own. “The sucking reflex…lends itself to repetitions and to cumulative use, is not limited to functioning under compulsion by a fixed excitant, external or internal, but functions in a way for itself. In other words, ***the child does not only suck in order to eat but also … he sucks for the sake of sucking***.” “The object sucked is to be conceived not as nourishment for the organism, but, so to speak, as aliment for the very activity of sucking, according to its various forms.” (35, emphasis added.)

I suggest that, beginning in early infancy, muscular movements are self-perpetuating and performed for their own sake. In later life, bodies that repeat actions on their own may be accompanied by minds that try to construct reasons for such actions. An older child or adult will also perform lifestyle, social and mental activities in self-perpetuating ways and will sustain and deepen an activity by means of repetition — “doing it for the sake of doing it.” I suggest that acting on one’s own, deepening performance skills through repetition and “doing it for the sake of doing it” identify primal principles that lead in many directions, including scientific directions. In science, as we shall see, they lead to “invariance” and “conservation.”

In my approach, muscular movements – especially repetitive movements – make up the ground of actual life. The word “actual” signals a discussion about muscular movements: e.g., movements involved in eating, digestion, breathing, looking, walking, handling objects, writing, speaking, gesturing. (Listening, dreaming and remembering can occur without muscular action.)

Rudimentary models employ continuous muscular activation; every muscle is activated all the time. It is only in advanced designs that inhibitory signals function as additional controllers. During operations of “An Eye for Sharp Contrast” (discussed in § 5a), every muscle-like fiber twitches continually; and the gaze shifts during each cycle. In animal bodies, opposing skeletal muscles, as modeled in the Dogtail, maintain constant tensions from which movements arise. In actual life, biological muscles involved in heartbeat, breath and digestion all work continually.

I suggest that an animal organism maintains a ***plenum*** of muscular activation and movement as the ground of all activities of its brains — insect, fish or human. One metaphor is a bucket full of wriggling earthworms. But flexion alternates with extension and tension alternates with relaxation. Activations are relative and graded and operations generate different kinds of movement. A fixed flow of energy (blood sugar) is insufficient to maintain high activations of all units. Rest after toil is needed in any event. Hence, distributions of activation are variable.

In my models, muscle-like activation is never lower than a level called ***tonus***, which sustains "muscle tone." However, in situations involving "quasi-static activations," actual motion is absent. Tonus is too weak to move a bodily mass. With a higher activation comes "balancing" operations in which opposing pairs of activated muscles hold body parts steady but ready to move. Actual movements require ***unbalanced*** operations at levels higher than tonus. Varying levels of activation and varying levels of ***readiness*** are behind behaviors ranging from a fully relaxed organism to one that launches itself into enraged attack.

In actual life, activated organisms are ready for action. Activities that require a high level of activation and readiness include performances in driving, sports and music mentioned above. High readiness is needed to "choose right" i.e., to select one "best" course of action from among multiple possibilities and to time actions so as to take best advantage of opportunities.

Actual life is grounded in muscular movements but, of course, actual life includes much more than muscular movements. Other parts of actual life (e.g., bodily drives, habits and training, rational methods, family, institutions) have ***control relationships*** with muscular movements. In my approach, higher-level constructions provide additional means to control and develop muscular movements. The organism has needs that require such control and development.

My approach aims first for operational or concrete control of movements and only at some later time for representational or symbolic control. Such an approach differs from computer models where representations are foundational. Here, representations are laid over primal controllers, which operate prior to representations. I suggest that sensory smells, sights and sounds start off as signals for action. Symbols and representations have origins in images that identify, index and encode selections, e.g., by use of labels. Development of imagery might re-trace biological evolution: insects have fixated imagery; reptiles have saccadic (jumpy) imagery; mammals have continually-streaming imagery; and human beings generate imagery of laws and institutions.

Development of imagery occurs when a child learns to "perceive things as we do, as objects that have substance, that are permanent and of constant dimension." Piaget, *Child's Construction of Reality* at 1. Chapter 1 of Piaget's *Construction* is titled "The Development of Object Concept." According to Piaget, "objects" are constructions; and psychological processes or "operations" perform constructions. Piaget thus teaches a practical and operational kind of epistemology or, employing terminology of an engineer, a model of knowledge construction.

In "Constitutive Processes of Object Concept," (*Child's Construction of Reality* at 87), Piaget compared "the formation of initial sensorimotor objects" achieved through "elementary processes of the child's intelligence" with "those used by scientific thought to establish the objectivity of the beings it elaborates." Piaget taught that an infant's mental activity adumbrates (foreshadows) and evolves into scientific disciplines. (See Piaget, *Structuralism*.)

"Initial sensorimotor objects" are based on an infant's ***sensory-motor activity*** that coordinates sensory organs and muscles, e.g., during play with crib toys. Sensory-motor activity is part of the infant's primal experience and is essential to development of perceptions of connectedness and orientation in a situation and for all later growth. (Piaget, *Child's Conception of Space*.)

"[T]he permanence of the object stems from constructive deduction" that "enables the child to build a spatio-temporal world of objects endowed with causality." (*Child's Construction of Reality*, 94.) Objects are subject to muscular movements and coordination. (*Id*., chapter 2.) "The problem is, therefore, to understand how the child succeeds in … constructing permanent objects under the moving images of immediate perception." (*Id*. at 91.)

Piaget thus teaches that psychological processes "build a spatio-temporal world of objects." In such a world, objects have features of ***substance, permanence and participation in a world of causality***. In adapting such teachings to my purposes, I construct distinct classes of "objects" and multiple "worlds." The construction starts with "actual objects," which leads to "sensory objects" and then to "mental objects." Mental objects, e.g., geometrical figures, are put into an "imaginary metaphysical domain," e.g., as represented on a chalkboard. Various imaginary domains contain rules of chess, Plato's Ideas, Laws of Physics and laws of the State of California.

Piaget's "initial sensorimotor objects" are what I call ***actual objects*** that are based on muscular movements; and such actual objects make up the ***actual world***. We pick up actual objects and push against actual objects. Another term for actual objects is ***material objects***. Such objects are made of specific materials and each material has a specific character. Clothes, foods and books are made from distinctly different materials and involve distinct classes of muscular movements. I suggest that all persons share a common background of experience of actual objects and a common actual world. We have a shared and ***common actual life*** that is rooted in a single, common bodily design and in common nervous, sensory, muscular and skeletal systems. In brief: all human bodies share a common repertoire of muscular movements. Therefore, we all understand clothes and foods and books much "the same." While moving our bodies, our brains operate in common ways that developed from those of early reptiles. I suggest that our common actual life based on muscular movements is the ground of personal interactions and of society.

The "actual world" behind my constructions serves purposes similar to those of a "real world" or "objective world" in other constructions; but there are also important differences between such worlds. An actual world is a result of muscular movements and does not have existence other than in the presence of actual life. Such an "actual world" is sparse and limited in comparison to a "real world" that extends over "the Universe" and that exists in the absence of life. On the other hand, an actual world avoids apparently insoluble questions about the nature of a real world. Is imagery real? E.g., does "reality" include an itch or next year's vacation plans? Does reality decide which runner wins a footrace or which litigant prevails in a lawsuit? An actual world construction bypasses such questions by beginning with movement and then adding imagery.

Additive constructions develop a class of sensory objects from sensory activity, often distinct and separate from actual objects. Sunlight and words of command acquire status as Piagetian objects with substance, permanence and causal influence. In my approach, such properties of sensory objects are based on adaptations of the substance, permanence and causal influence of actual objects. Sensory objects also have an independent status and develop in their own ways. For example, we know by muscular activity that actual objects have a rigid character or an elastic character. We impute similar characters to sensory objects, extending our muscle-based knowledge and allowing for new variations. At least at the start, sensory objects are based on actual objects.

Some sensory objects can be detected from a distance and others can be seen on a TV screen. Birdsong, clouds and celestial bodies (sun, moon, stars) are sensory objects. The sun appears to have a fixed shape except during rare eclipses while shapes of clouds are always changing. The shape of the moon changes in a cyclical way. Scientific explanations for these phenomena are stated in terms of force, mass and inertia that have a conceptual origin in muscular action.

An object's class may depend on the person who constructs it. A concert violinist constructs an actual object while playing a melody in contrast to a member of the audience who constructs a sensory object while listening to it. The violinist exercises freedom in shaping the melody through muscular movements but the audience member has only the choice of attending or not.

Sensory objects come in larger and more varied classes than actual objects. As a rough measure, there are more persons in the audience than on the stage. Based on the variety of opinions that are typically expressed, audience members may have disparate auditory experiences. Although all persons use much the same basic muscular movements, each person favors particular music, videos and flavors. Unlike actual objects that can be tested by muscular movements and identified according to the common standards of actual life, sensory objects often generate disputes about their existence or nature. In contrast to contests of muscular performance that result in victory or defeat, disputes about sensory objects usually have no clear resolution.

Mental objects make up a third distinct class of objects: these objects start from actual objects or sensory objects; the person then uses additional processes to construct relations and structures that are detached from muscular movements and from any original context of movement. This means, e.g., that a mathematical object cannot have "speed," "weight," "mobility," "texture" or other muscle-based feature. Mathematical elements such as numbers, equations and circles are exemplary mental objects. Symbols identify mental objects. A played tune and a spoken message can be reconstructed as purely mental objects and put into symbolic form.

Symbols such as words and musical notes can represent and organize sensory objects and mental objects in imaginary domains. In contrast, muscular movements are difficult to symbolize. For example, books of instruction for yoga practice rely primarily on pictures. I suggest that mental objects appear in imagination and have characters that are different from those of actual objects that are based on muscular movements. I suggest that mental objects are developed on top of layers of actual objects and sensory objects but that they also have their own character. The three classes of objects make up a layered construction with each layer having a distinct and independent character and with developmental relationships between layers.

Some mental objects and muscular movements are handled "the same" by certain psychological operations, e.g., operations that match and operations that count. Other operations such as focusing, following and balancing work somewhat differently as to actual objects and mental objects. Actual objects are unique and have individual characters; events in the actual world are irreversible. Mental objects, on the other hand, come in classes of identical objects and in classes of objects with smoothly variable features. In imagination, events involving mental objects reverse and occur in different ways; and mental objects can be re-used, re-combined, re–organized, re-tuned, etc. Diverse kinds of mental objects include fantasies, e.g., imagery of a unicorn or fantasies of flying like a bird. Some mental objects, e.g., numbers, are common to all persons; some are shared in a distinct community, e.g., a cult; and others are entirely private.

Often, a person uses mental objects to control muscular movements, e.g., the mental image of an equilateral triangle used as a drawing guide. Also, recalling the introductory examples of freedom: traffic laws, game plans and musical scores are used to control muscular movements. ***Forms*** is a class of mental objects that are used as guides for actual movements. Such uses occur in ***performances***, episodes of action during which forms guide actual movements.

This essay constructs, compares and contrasts two classes of forms, namely, ***spatial forms*** and ***temporal forms***. Important spatial forms such as lines and circles are based on geometry.

Geometry also includes some temporal forms. For example, in plane geometry there are multiple different ***ways*** (temporal forms) to construct a bisected angle from an angle; the resulting bisected construction is a unique spatial form and the uniqueness is proved. Temporal forms are predominant in music and sports. There are also ***empty forms*** that completely fail in attempts to guide actual performances, e.g., a form for flying like a bird by flapping one's arms.

As geometrical constructions, music and automobile travel demonstrate, muscular movements are sometimes controlled successfully by means of forms. Such demonstrations occur in specific situations, such as math class or the freeway. In my approach, muscular movements can have multiple kinds of control, e.g., control by laws (forms), control by a parent or self-control by a person seeking to achieve goals. Attempts at control by means of forms are sometimes successful and sometimes not. Even when successful, control by means of forms may be less efficient than other kinds of control. For example, sometimes a series of authoritarian commands gets the job done in a situation where trying to explain principles would take too much time.

c. Infantile repetition develops into scientific invariance.

In a further stage of development, I suggest that psychological processes construct ***invariant objects***. Invariant objects incorporate a key principle, namely, a rule of invariance. Like the actual, sensory or mental objects on which it is based, an invariant object has a repetitive or matching feature or character; but, in addition, it has that feature or character ***every single time*** and it ***cannot lack that feature or character***. Rules of invariance have various or sundry bases, e.g., design, inherent operations, experience, reason, authority, habit or refusal to use better tools. I suggest that mathematics and sciences are built around closed, compact sets of invariant objects. I suggest that small children, as well as adults, construct and impose rules of invariance for the sake of doing it. "You have to hold it the way I showed you." "Why?" "Because I said so."

Actual objects and invariant objects are both psychological constructions and can resemble each other. However, as a practical matter, a person recognizes that every actual object is subject to change. No material object will function in a desired way "forever." When failures happen, such an object is said to "to break" or "to stop working." Each living organism arrives at death.

The various classes of objects have different characters and features. Each actual object is unique and different from every other actual object; but invariant objects exist only in minds and are generated in classes of "identical objects" or "families of objects," e.g., "circles," "numbers," "atoms." Some actual objects such as "AA batteries," chemical reagents or "atomic beams" are produced through technology to more closely resemble invariant objects than objects found in nature. Such actual objects and invariant objects work together satisfactorily in some situations, such as science laboratories, consumer electronics and fast food franchises. Attempts to use them together in other situations, e.g., government regulation of business, are less successful.

Rules of invariance can have many beneficial advantages that encourage efforts to construct them and impose them on physical materials, objects, persons, behavior and imagery. An invariant object has reliability; it can be re-used easily, without need to weigh possibilities. A class of objects that have functional invariance, e.g., violins, control muscular movements of a class of persons. An organized system of such objects, e.g., musical instruments in a symphony orchestra, can help develop a culture. Something that lasts, that endures "the same" over a lengthy period of time, has inherent value based on that fact alone. In the final moments of the classic film *Gone with the Wind*, the voice of Gerald O'Hara, deceased, speaks to his daughter

Scarlett about their plantation, Tara: "Land is the only thing that matters. It's the only thing that lasts." (He neglects memory, which is foundational.) I suggest that life would be simpler if we had more principles that all the folks agreed on all the time. Boiled down to practical necessity, "invariance" is a principle of importance in all matters of knowledge and action because we have nothing better to use. Therefore, we use it on all possible occasions, for the sake of doing it.

Ancient Greek philosophers embarked on "the search for invariants, which is the definition of science." (de Santillana, *The Origins of Scientific Thought*, 218.) "It is the observation of celestial motions, which challenged men to search for the impersonal *invariants* behind events. This is after all what science means." (12, emphasis in original.)

Science has successfully investigated some "impersonal invariants behind events," such as events where bodies descend from a height under the influence of gravity. Please recall imagery of Galileo dropping balls from the Tower of Pisa or, better, rolling them down a ramp. A question is presented as to whether impersonal invariants like gravity are behind ***all events*** or whether there are some events that have a different basis. The skeptic says: Yes, there are invariants. Invariance is a good idea. But is invariance all-powerful in some "universal" way?" Does invariance control everything?

In my view, rules of invariance are psychological constructions that persons try to impose for the sake of imposing invariance and because the results are sometimes beneficial. Comparing such rules with actual life, the practical world of my experience does display broad examples of invariance, e.g., seen in movements of motor vehicles and pedestrians in response to traffic signals. But there are also exceptions, such as the ambulance with siren sounding; and the system requires continual repairs and modifications just to keep things going. Contrary to the kind of world that would be controlled by impersonal invariants, there is very little in my world that all folks agree on. Instead, folks are occupied with troublesome disputes, decisions and adjustments that require personal efforts, personal choices and personal favors. My world is filled with individual characters doing it for the sake of doing it. Novelties are continually appearing and few events conform fully to expectations. In sum, I conclude that actual life refutes any claim that "impersonal invariants" govern each and every course of events.

Some scientists teach that impersonal invariants do control all events. Roger Penrose, a self-declared platonist, wrote of "the mathematical scheme which governs the universe." (*Emperor's New Mind*, p. 433.) Richard P. Feynman thought that "if we could figure everything out, we would find that there is nothing new in physics which needs to be discovered in order to understand the phenomena of life." (*Character of Physical Law*, 151.) Computer intelligence advocate Marvin Minsky declared (*Society of Mind*, § 30.6.): "According to the modern scientific view, there is simply no room at all for 'freedom of the human will.' Everything that happens in our universe is either completely determined by what's already happened in the past or else depends, in part, on random chance."

I suggest that such scientists are in error when they claim that all events are controlled by impersonal invariants and/or by "random chance." Rather, knowledge so based has only a limited reach and there are phenomena outside that reach. I suggest that errors in over-reaching claims are revealed by means of alternative constructions. I suggest that episodic balancing forms generated by devices proposed in new technologies can have individualized outcomes that depend on critical moments of transformation. Such activities are often very different from those described and controlled by impersonal and invariant forms of platonic science.

d. In contrast to empty constructions of "will" and "free will," science and technology have had good luck with metaphysical constructions.

"Free will" is a construction that purports to combine "freedom" and "will." The construction and the underlying concept of "will" were unsatisfactory even for the purposes of Augustine (354-430), the inventor of "free will." Augustine was trying to fit freedom into his forms of Predestination and Grace. (Pelikan, 323-324.) Augustine's "will" is a combination of "our power to confer or withhold all-things-considered assent, or choice" and "the basic disposition of our being," e.g., "good or ill will." (Taylor, 138.)

Such concepts and constructions of "free will" are defective, in my view, because they are limited to imaginary domains. So-called applications such as the free-will experiment of § 1 fail to involve streams of muscular movements but chiefly focus on operations with images. I suggest that diverse concepts of "will" set forth at various times by various writers – e.g., Augustine, Nietzsche, James – fail to cohere amongst themselves and fail to apply to actual life.

In a ***metaphysical construction***, mental objects exist and act in an imaginary domain, such as the spatial domain of a geometrical demonstration, a domain of electronics signals implied in an engineer's circuit diagram or the domain implied by the Vehicle Code (traffic laws) of California. Imaginary domains in the three examples connect to actual life. Other imaginary domains such as those in movies, novels and fantasies need not connect to actual life. Augustine and his successors reworked Greek psychologies into a metaphysical concept of "will." (Taylor, 137.)

In an ***application***, metaphysical principles guide muscular movements of persons, e.g., one who is building devices from materials or who is operating a motor vehicle. My practical approach requires an application to give actual content to constructions. Some metaphysical constructions, e.g., those that use solid geometry and Electromagnetic Waves, do have actual applications, e.g., in grinding optical lenses. But other constructions do not have applications. The obsolete scientific construction *phlogiston*, for example, has no applications. A requirement of actual applications is demanding and excludes many scientific concepts, e.g., "string theory." I use the word "empty" for metaphysical constructions that may exist in imagination or "reality" but that lack connections to actual life. Empty forms do not guide a person's actual muscular movements.

I suggest that Augustinian "will" is an empty metaphysical construction and that later concepts of "will" do not overcome the defects. Suppose that, while exercising the "power to confer or withhold all-things-considered assent," (Taylor), it is "will" that controls muscular movements. Such a notion, if substantiated, would apply directly to actual life. However, such notions do not recognize that animal bodies move on their own prior to assent or imposition of controls. As discussed in § 5, modern science provides no suggestion for "willed" activation that is any more satisfying than Descartes' suggestions about the pineal gland.

I suggest that science pursues empty models in which images cause muscular movements. In my view, muscles are always activated and the organism is moving or ready to move; movements occur on their own; images also occur on their own; muscular movements generate images; images based on forms can entrain with images based on movements and partially control movements; image operations can influence selections, switches and guidance of movements, including movements that are already happening. But movements are transient, in contrast to sustained formal imagery. Selections – where multiple possible movements turn into actual movements – often involve freedom. Actual movements depend in individual ways on happenstance aspects of specific situations as well as on imagery that includes invariance.

In sum, concepts of "will" and "free will" do not connect to muscular movements. We exercise freedom through streams of small actions, as in driving a car. Even a large-scale exercise, such as running a race or reaching a verdict, requires a series of steps. "All-things-considered assent" does not apply to these tasks. The "all-things-considered" need is to complete the trip safely, to win in sports and to get the case decided for a judge or jury. So-called "powers of choice" ignore difficulties of performance or contrary arguments. Actual choices involve trade-offs between desired and undesired features and actual choices require efforts to bring them about. Possible movements turn into a particular movement and a need drives a choice that is influenced by deadlines, trade-offs and reluctances. "Free will" denotes an empty choice that is not driven by need; it is a choice without stakes or effort, like gambling at roulette with play money.

Although metaphysical constructions of "will" and "free will" are empty, the wider history of metaphysical constructions shows facts of substance and opportunity. Certain metaphysical constructions have led to tremendous successes of platonic science with wonderful applications in practical technologies and intellectual progress in highly important areas of investigation, e.g., those surrounding Newton's Mechanics (incorporating absolute time and space) and Maxwell's Electromagnetic Waves (implying a luminiferous or "light-bearing" ether).

Such examples also demonstrate that metaphysical constructions incorporate errors. Features of the examples ("absolute time and space" and "luminiferous ether") were once believed to be real; but they were shown to be fallacious by Einstein's superseding construction, the Theory of Relativity (1905), which astonished many scientists and which also showed an astonishing equivalence between mass and energy. Hence, none of our current metaphysical constructions is reliably error-free. (Popper, Nature of Philosophical Problems.)

Most important, metaphysical constructions have achieved lasting practical value based on their embodiment in technologies. Technologies based on metaphysical constructions outlast belief in the metaphysics. Astronauts' navigation is based on Newton's Mechanics, not that of Einstein. Earthly nautical navigation still holds that the Earth is the center of the Universe.

As a more detailed example, the current view among physicists holds that "light is photons" is "true" and that "light is waves" is "false." Between the enthronement of Electromagnetic Waves in 1865 and their overthrow in 1905 — during "the short happy life of the luminiferous ether" — physicists believed that "light is waves" was true; but Einstein (and others) showed such beliefs to be untenable. In such statements, "light" refers to something "real" and such reality is stated in mathematical constructions, either as "photons" or as "waves." According to invariance principles, such constructions must be true everywhere and eternally. Physicists now hold that mathematical photons have some reality that mathematical waves lack (which demonstrates the metaphysical character of Electromagnetic Waves). Despite the supposed inferior status of waves, technologies based on waves – e.g., microwaves and lenses that aid vision – are so firmly established that their development continues to progress through means that often ignore photons.

The history of science and technology thus reveals a fortunate if puzzling paradox. Erroneous metaphysical constructions have led to successful technologies. Conversely, technology can be based on metaphysical constructions regardless of the exact conformity of such constructions to "truth" in the sense of "fit to reality." The value of metaphysical constructions may be based on successful technological applications rather than on "truth." A noteworthy epigram of Goethe states: "A false hypothesis is better than none." (Kaufmann, Discovering the Mind, Vol. I., 45.) For a practical person, "better" is shown by success of technology.

In other words, a practical person might look for new but as yet un-built metaphysical constructions that can be embodied in new technologies. The goal is productive results rather than a claim to "truth" or "reality." To help aim at the goal, critical reconstruction of existing and past attempts can identify errors and limitations that might be overcome in fresh endeavors.

I have followed such an approach and am developing new technologies —***Quad Nets*** and ***timing devices*** — that embody new principles of action and freedom. Designs include "An Ear for Pythagorean Harmonics" (2009), "An Eye for Sharp Contrast" (2011) and constructions in this essay, e.g., " A Dogtail for Wagging."

I am not trying to "explain" brains, e.g., with a "theory." My approach does not support a "theory." Instead, I propose new ***kits of parts***. Kits of parts are practical and have a mathematical and engineering character. An existing kit of parts that serves as an exemplar of the form is made up of "standard electronics components" (resistors, capacitors, transistors, microphones, etc.) used in radios and computers. The timing devices kit of parts resembles the kit of parts of standard electronics components. The timing devices kit is also an application of the more abstract kit of Quad Net devices. There are currently no working models of any of my proposed devices and all designs herein are acts of imagination.

My kits of parts are presently only imaginary, but I look forward to the manufacture of physical devices that are hooked together on an engineer's bench. Then some of my own errors and limitations will be made clear and developers can invent newer and improved devices and principles. Operational systems that use manufactured timing devices and Quad Nets — especially newer and improved versions — will be actual applications of my metaphysical constructions.

2. Nietzsche's "will to power" shows the defects of metaphysical constructions that fail to connect to actual life.

Nietzsche invented "will to power," declared it to be the sole cause of actual life and based an elaborate construction on it. The construction is flimsy and childish; its defects highlight those of Greek philosophers who founded platonic science and those of modern platonists. Nietzsche himself criticized such constructions on grounds similar to those I state.

Please see Nietzsche's *Beyond Good and Evil* § 36 (Walter Kaufmann trans.) for the chief quoted matter, with emphases copied from the text. The passage is set forth and discussed in Kaufmann, *Discovering the Mind*, Vol. II at 75 *et. seq.*

Nietzsche begins with "our world of desires and passions." He proposes that there is no "other 'reality' besides the reality of our drives." He decides to "make the experiment" that such a reality is "*sufficient* for also understanding … the so-called mechanistic (or 'material') world."

Nietzsche continues by positing "several kinds of causality," including "the causality of the will." He embarks on the further "experiment of positing the causality of the will as the only one." He "has to risk the hypothesis" that "all mechanical occurrence are effects of will."

Nietzsche's construction thus proposes a single "causality of the will" in a "world of desires and passions" that generates and comprehends all other "reality." That causality becomes "will to power." The construction supposedly suffices to "understand" physical mechanisms, material bodies and, presumably, all phenomena of actual life.

In attempting to connect his construction to actual life, Nietzsche conceives of a "pre-form of life," "a kind of instinctive life in which all organic functions are still synthetically intertwined, along with self-regulation, assimilation, nourishment, excretion, and metabolism."

"Suppose, finally, we succeeded in explaining our entire instinctive life as the development and ramification of *one* basic form of the will—namely, the will to power, as *my* proposition has it. … then one would have gained the right to determine *all* efficient force univocally as—*will to power*."

Nietzsche also wrote: "the will to power is the primitive form of affect … all other affects are only developments of it…all driving force is will to power…there is no physical, dynamic or psychic force except this…It is simply a matter of experience that change never ceases: we have not the slightest inherent reason for assuming that one change must follow upon another … Spinoza's law of 'self-preservation' ought really to put a stop to change: but this law is false, the opposite is true. It can be shown most clearly that every living thing does everything it can not to preserve itself, but to become *more* —" (*Will to Power*, § 688, emphasis in original.)

Value is a focus of power, according to Nietzsche: "value is the highest quantum of power that a man is able to incorporate." (*Id.*, § 713.) He views it as "a standpoint of conditions of preservation and enhancement for complex forms of life-duration within the flux of becoming. [¶] There are no durable ultimate units, no atoms, no monads: here, too, 'beings' are only introduced by us (from perspective grounds of practicality and utility)." (§ 715.)

Nietzsche's construction resembles platonic constructions in which a metaphysical domain is occupied by eternal mental objects. Comparing constructions of Platonic Ideas, Laws of Physics and Will to Power shows that all are single-minded: a single kind of mental object is said to control everything else.

As for contrasting features, Nietzsche's generative element is distinctly different from platonic elements. Chiefly, "will to power" is an element of ***transformation***, in contrast to platonic constructions, where Ideas and Laws of Physics are elements of ***conservation***. Platonism would establish a hegemony of eternal Ideas or Laws while will to power would establish a hegemony of change. Under the hegemony of change, where, according to Nietzsche, "change never ceases," stronger changes dominate weaker changes. In imagery filled with whirling changes, will to power feeds on growth and seeks to grow more. It embodies single-minded change with a metaphysical essence that permits nothing but growth, struggle and domination.

Nietzsche's construction turns biological desire into metaphysical will and makes it the sole primal principle. According to this principle, a value is measured by a "quantum of power" that has a direction, namely, "more." Single-minded "more" values all have the same form. In Nietzsche's imaginary world of whirling changes where will to power, drives and single-minded "more" values are the only sustained features, some "more" values lead to very little more while other "more" values lead to a lot more. Will to power is by definition the sole generator of all values; and it is a betrayal of that value to accept anything less than a lot more value and a lot more power. For a meaningful life, according to Nietzsche, you must embrace and uphold will to power in a single-minded way and you must get more, more, more!

The "will to power" does not stand up to critical examination. Nietzsche himself argued against single-minded mental conceptions. [*Twilight of the Idols*: "The error of free will" — "the world does not form a unity either as a sensorium or as a spirit."] Nietzsche's single-minded mental conception suffers from defects common to the class. [*Id*.: " 'Reason' in Philosophy."]

"The metaphysical conception of the will to power as the ultimate reality behind the world of appearance conflicts with Nietzsche's emphatic repudiation of any such two-world doctrine." (Kaufmann, *Discovering the Mind*, Vol. II, 77.)

Plato refuted will to power in *The Republic* through the figure of Thrasymachus. Shakespeare wrote of folly that occurs when "every thing includes itself in power, Power into will, will into appetite, And appetite, a universal wolf, so doubly seconded with will and power, Must make perforce a universal prey, And last eat up himself." (Troilus and Cressida, Act I, Scene iii.)

Like Plato, Nietzsche did not ground his inventions in actual life but rather in mental conceptions that he preferred to actual life. Although Nietzsche claimed to base his construction on "our world of desires and passions," such a basis is not established. In my view, desires and passions are grounded in muscular movements and bodily activity. Most of my actual activities are directed towards satisfying essential bodily needs (eating, hygiene and sleep) and satisfying body-based desires for home, comfort, movement, adventure, sensation and society. I suggest that other persons generally engage in similar activities in similar ways. Such activities do not conform to assertions that "our entire instinctive life" is expressed through "the development and ramification of *one* basic form of the will—namely, the will to power, as *my* proposition has it." For me, desires and passions seem to be in control and my powers to satisfy them are limited.

The construction has deeper defects. Starting from a base of "desires and passions," Nietzsche declares that his construction encompasses mechanical and material causes. He does not ask whether his construction has fallen off its base or whether the base has shaped development. He never reviews his experiments, risks and hypotheses. He never considers that "our world of desires and passions" might run up against limits from physical constraints or moral restraints. He appears to deny any need to consider constraint or restraint.

The subject of causality has attracted many investigators and generated many tomes of philosophy, psychology, physical science and jurisprudence. Questions of "free will" and the causal power of will, such as Nietzsche presumes, are important for some causal investigators but by no means all. Wallace's 2-volume historical review, *Causality and Scientific Explanation*, has but two references to "freedom," quoting scientists who declined to make a connection between issues in scientific causality and human freedom or will. Nietzsche blithely ignores such history and imposes a single, highly problematical kind of causality, where "the causality of the will [i]s the only one." Without consideration of facts of mechanical or material phenomena, he reduces them to "will." He claims to control all such phenomena through his imagination.

Nietzsche uses metaphysical constructions like "will to power" as elixirs of self-intoxication. "For the game of creation, my brothers, a sacred 'Yes' is needed: the spirit now wills his own will, and he who had been lost to the world now conquers his own world." (*Zarathustra*, "On the Three Metamorphoses of the Spirit.") My conclusion is that self-intoxicated Nietzsche neglected skills of self-criticism. His "will to power" construction is indistinguishable from a "wish" construction and lacks a backbone of discipline.

Notwithstanding defects and limitations, Nietzsche's will to power, like platonic science, contains features that are useful in my own approach.

As noted above, Nietzsche criticized metaphysical constructions that he called "the two worlds," where a metaphysical world of permanent knowledge supposedly controls a transient world of appearances. (Kaufmann, vol. II, 76.) He compared and contrasted two-world constructions in ancient and modern sciences. (*Beyond Good and Evil*, § 14.)

However, instead of populating a separate, metaphysical world with eternal mental objects in the style of platonic Ideas, Nietzsche used a primal element of change, "will to power," that acts in response to changes and that causes changes. Will to power is transformational while platonic Ideas and platonic science are form-conservational. Will to power generates its own metaphysical world of growth and change instead of occupying a metaphysical world that is defined by mandatory meta-forms in which it must operate and which it must maintain. Hence, "[t]here are no durable ultimate units, no atoms, no monads."

Discussion in § 3 below involves a chief metaphysical construction of ancient Greeks, namely, Being, which was treated by them as "real." For Nietzsche, however, "beings" are "only introduced by us" on the basis of "practicality and utility."

Most important, Nietzsche tried to ground his construction in "a kind of instinctive life" that revolves around activity of a person's animal body such as "nourishment, excretion, and metabolism;" and he gave his construction a primal unity prior to differentiation into separate functions. He reached towards principles that "drives" are based on bodily processes and that "will" is based on self-perpetuating muscular movements. "Will to power" is an attempt to generate through a single developmental principle all the multiple aspects of personality — bodily, mental and emotional — as well as multiple stages of development. Nietzsche sought to integrate the multiplicity into a living organism while, in contrast, platonic science seeks first to separate the elements and then to control them according to principles of mechanism and chance. According to Kaufmann (*Discovering the Mind*, Vol. II, 71-72), Nietzsche was trying to develop the self-negating "will" of Schopenhauer into an improved version that is life-affirming.

I suggest that Nietzsche carried out a partially successful investigation into his own primal psychology. However, the fruits of the investigation were not the sought-after keys to the universe. They were, rather, certain childish thought processes that Nietzsche dressed up in grandiose phrases and tried to inflate into a comprehensive world-view. Because Nietzsche's thought processes were authentically childish, they incorporated primitive aspects of actual life that differ from the detached constructions of platonic science. Surprising, even shocking juxtapositions appeal at first to childish dispositions and then reveal genuine substance. Seen next to the vibrancy of Nietzsche's childish primitivism, platonic science appears pale and weak.

Nietzsche's childishness is shown by Piaget's *Judgment and Reasoning in the Child* (1928), where, in "Summary and Conclusions," Piaget described "the most characteristic" kind of thought of children under the age of 8 years as "ego-centrism." It is manifested as "that quasi-hallucinatory form of imagination which allows us to regard desires as realized as soon as they are born." A child "has the peculiar capacity for immediate belief in his own ideas." "On the plane of verbal thought, every idea pictures a belief." "…it is extremely difficult for him to distinguish between fabulation and truth." "Only in his manual games does the child learn to understand the resistance of objects." (202-203.)

At about age 6-7, " 'artificialist' explanations given by children of natural phenomena are very frequent: rivers, lakes, mountains, sea and rocks have been made by man. Obviously, this does not require the slightest proof: the child has never seen people digging lakes or building rocks, but this does not matter. He enlarges sensible reality (a bricklayer making a wall, or a labourer making a ditch) by means of verbal and magic reality which he puts on the same plane." (203.)

Childish thought develops into adult thought. However, adults have learned from failures of ego-centrism and therefore limit and constrains act of imagination. "We are constantly hatching an enormous number of false ideas, conceits, Utopias, mystical explanations, suspicions and megalomaniacal fantasies, which disappear when brought into contact with other people." (204.)

In his construction of will to power, Nietzsche manifests a quasi-hallucinatory form of imagination in which his fragmentary "will to power" concept has magical, controlling power not only over all other concepts but also over physical forces and materials. He conflates two worlds that adults use to distinguish desires from deeds. For Nietzsche, like young children, desire is felt to produce deeds out of an essential inherent power that overcomes any resistance.

Like children's "artificialist" explanations, Nietzsche's "will to power" explanation does not require proof. His concept might apply to some actual activity and any such application is sufficient for his belief in its universal power. He never considers the possibility that his inventions are "mystical explanations" or "megalomaniacal fantasies" that would disappear if examined critically.

The method of construction employed in Nietzsche's will to power is similar to those employed in other metaphysical constructions. His is illuminating because he does not clothe his method in a scholarly apparatus or try to smooth over the joints. He reveals how, in such constructions, particular mental processes are first grasped through introspection, observation and invention. Then processes are isolated, given a form and treated as if operating in a separate, imaginary domain. I suggest that much the same method was and is used by pre-Socratic philosophers, by Plato and his successors, and by present-day platonic scientists. My own metaphysical constructions employ such methods in new ways and with different forms and embodiments.

3. In metaphysical constructions that were developed by ancient Greeks as part of "platonic science," an imaginary domain is occupied by mental objects called "Ideas" that are impersonal and eternal, that have the rigid symmetries of geometrical space and that are supposed to control actual lives of persons.

a. Hegemonies in platonic constructions.

In *The Open Society and Its Enemies* (1950), Karl R. Popper showed how Plato's metaphysical constructions reflected political positions that were formed during the ruinous Peloponnesian War and during Plato's public career of supporting aristocrats and oligarchs and opposing Athenian democracy. Plato sought "an ideal state which does not change." "Plato also extended his belief in a perfect state that does not change to the realm of 'all things.' " He had a "belief in perfect and unchanging things, usually called the *Theory of Forms or Ideas*, [which] became the central doctrine in his philosophy." (24.) Plato's Theory had several functions, including "forging of an instrument for arresting social change, since it suggests designing a 'best state' which so closely resembles the Form or Idea of a state that it cannot decay." (33.)

In a passage from the *Laws* quoted by Popper (9), Plato wrote: "nobody … should be without a leader. Nor should [he] do anything at all on his own initiative … But in war and in the midst of peace—to his leader he shall direct his eye and follow him faithfully. And even in the smallest matter he should stand under leadership … never to dream of acting independently, and to become utterly incapable of it."

Plato's moral philosophy teaches a "***hegemony of reason*** in contrast to that of glorious action." (Taylor, 117, 120, emphasis added.) Reason connects us "with the order of things in the cosmos. …it is only on the level of the whole order that one can see that everything is ordered for the good. …the right order in us is to be ruled by reason … love of the eternal, good order is the ultimate source and the true form of our love of good action and the good life." (122.)

In sum, Plato's metaphysical constructions had an actual grounding in his political career. He opposed all change, other than to impose his visions, and he wanted a hierarchical enslavement state resembling Sparta. A philosophical hegemony of reason over action, stated by Taylor, is at one with a political hegemony that demands total obedience and that prohibits change. Such unified hegemonies can and do claim divine, philosophical and practical authority.

Plato's goal of imposing hegemonies re-appears in his famous metaphysical "divided line" that supposedly distinguishes and elevates "true knowledge" above "mere opinion." Plato's Ideas such as Perfect Beauty and Justice and mathematical forms such as triangles are objects of true knowledge and have a status superior to that of worldly objects and changing phenomena, such as those encountered in actual life, about which we can have nothing more than opinions, beliefs and conjectures. (de Santillana, 201.) Plato's line thus distinguishes between "real, certain, indubitable, and demonstrable knowledge – divine *scientia* or *episteme*" and matters where knowledge is "merely *doxa*, human opinion." (Popper, Nature of Philosophical Problems.)

b. Hegemony of impersonal invariance in metaphysical domains.

I suggest that establishing conceptual hegemony is a chief purpose of platonic scientists and shapes the content of their constructions. Such scientists do not simply “search for the impersonal *invariants* behind events” or conduct a “search for invariants, which is the definition of science.” (de Santillana, 12, 218.) Platonizing advocates of the “modern scientific view” (e.g., Minsky, supra) want to allow as legitimate only particular kinds of invariance.

Aristotle, who “swerve[s] away from mathematics” and “takes his start from things,” concurs in the supremacy of invariance: “There is no science except of the general.” (de Santillana 210-211.) “The universe makes sense as something eternal and diverse and eternally well-ordered. On this Aristotle claims to find himself in complete agreement both with Plato and with the Pythagoreans.” (213.)

“Aristotle, true to his antimathematical bias, has no quantitative conservation principles like ours, but the Act, that is the actualized Form, is there forever dominating change. It is the Form in Act that is conserved. …our word ‘act’ in Aristotle’s Greek is *energeia*. There was a possibility of reinterpretation that did not escape the subtle mind of Leibniz. In Aristotle, it comes straight from Plato.” (218-219.)

The confirming characteristic of “impersonality” is a form of invariance. Events that depend only on “impersonal” influences must come to the same result, regardless of the person who performs the action. Arithmetic is impersonal. Outcomes of scientific experiments cannot depend on the personality of the experimenter. The polar opposite possibility is that events depend on “personal efforts” or “personal favor,” where, by such means, one person can achieve an outcome that another person cannot. “Personal efforts” and “personal favor” vary from person to person. Sports competitions are designed to be decided by personal efforts. Changing moods of mass personal favor are aroused and seduced by marketers of clothing fashions, hairstyling trends and popular culture. Judges often favor one party or another when resolving disputes in court. Yes, “impersonal” influences do occur but they are not the only influences.

I suggest that “impersonal invariants” supposedly “behind events” are mental constructions that occupy an imaginary metaphysical domain. Assertions in ancient times, same as today, are that such mental constructions control both celestial motions and events of actual life. In ancient times, for example, astrologers constructed an imaginary celestial domain “behind” events, tracked its objects and relations and predicted actual events on the basis of their constructions.

In sum, platonic Ideas, Laws of Physics and other mental objects have been constructed by means of psychological imagination and are continually reconstructed by the same means. Such constructions extend those introduced in § 1 as part of the child’s construction of reality and resemble those discussed in §2 in connection with Nietzsche’s will to power. The elements that make up such constructions are based on the author’s mental processes. In other words, the author of such a construction obtains imagery of his own psychological processes by means of introspection, observations and inventions; endows the imagery with supposedly-powerful “impersonal invariance” in an imaginary domain; elaborates such imagery in symbolic constructions; and declares that imagery so endowed and elaborated is in control of everybody’s actual life. Impersonal invariance supposedly overwhelms any influence arising from personal efforts or an individual character. Advocates of such imagery assert authority to expound it, claim to transcend its “human-all-too-human” origins and promote its hegemony.

c. "Principle of sufficient reason" imposes eternal symmetries and indifference.

"Invariance" is one principle of science that stems from repetition. Another is the "principle of sufficient reason," which states: "Until a definite reason to the contrary can be assigned, we have to suppose a symmetrical distribution of things or possibilities." (de Santillana, 34-35.) "Symmetry" means that features are systematically repeated within the situation. Images from distinct areas match each other. I suggest that symmetry, like invariance, is a mental construction based on repetition and matching.

Using the principle of sufficient reason, a scientist argues that if one part of the Earth preferentially attracts the north pole of magnets, it must be because of some asymmetry in the body of the planet and/or its surroundings. According to this principle, events are presumptively symmetric in all respects except for respects specifically shown otherwise. This means that special imaginary domains can be constructed — such as "empty space" — where rules of invariance impose symmetries and vice versa. Platonic science treats such symmetrized imaginary domains as having foundational control over all phenomena of actual life.

An important application of the principle of sufficient reason is Newton's First Law of Motion, which states: "Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon." Newton's Laws and motions thereunder take place in an imaginary domain of empty space that starts off devoid of influences or forces. This is a domain in which the principle of sufficient reason operates. Suppose that an object in motion in empty space travels a short distance in a certain specific direction in a certain short period of time. In the next short period of time, there is no reason for it to go in any direction other than that previously traveled; therefore, applying the principle of sufficient reason, it continues to move in the same direction. Likewise, there is no reason for it to go faster or slower, so it continues with the same speed.

I suggest that the principle of sufficient reason applies weakly, if at all, to many occurrences in actual life. A person walking on a level surface can often move with equal effort in multiple directions and prior steps do not determine the next step. In actual life, a person continually generates streams of possible movements and makes selections to produce actual movements. Persons start and stop streams of movements, select courses of action and switch to and fro. Events and changes occur in actual life for good reasons, for poor reasons or for no reason. Changes sometimes occur on large scales in ways that can't be explained by reasons. Often it is possible to correlate changes with reasons; but frequently such correlations cannot be made.

Applied to empty space, the principle of sufficient reason says that every place in empty space participates in a "sameness" that enables a person to imagine that one geometric figure is relocated and "superimposed" on another geometric figure. "Sameness" means a repetition when different places in space are compared ("***homogeneity***") and when different directions are compared ("***isotropy***"). (de Santillana, 95.) However, such symmetries do not generally apply to activities of actual life. Events occurring at different times often can't be superimposed; or superimposition requires disregard of differences. People have clashing views and perspectives.

As shown by Newton's First Law, there are situations where the principle of sufficient reason can be applied to periods of time as well as to spatial symmetries. Newtonian "speed" is treated much like "direction." Combining an invariance principle with the principle of sufficient reason leads to invariances that are permanent until a definite reason arises to change them. In the absence of such reasons, this gives "impersonal invariants" the character of ***eternity***.

The principle of sufficient reasons also establishes a ground of ***indifference*** in which individualized characters are denied a place to root. Everything starts the same and any distinction must be traced to a specific reason that has causal power. Nothing happens on its own. In advanced platonic constructions, important roles are given to "probabilities" that are grounded in indifference. E.g., as discussed below, statistical mechanics stands on the "fundamental hypothesis of equal *a priori* probabilities." (Tolman 59, 350.)

In sum, in platonic science, metaphysical processes of construction create an imaginary domain populated by invariant objects. The invariant objects may resemble actual objects or sensory objects but they are eternal, impersonal, symmetrized and/or indifferent. Such invariant objects have a resemblance to actual objects that is like the resemblance of Greek gods to human beings. According to many teachers, e.g., Plato, such invariant impersonal mental objects in imaginary domains control - or should control - actions of human persons engaged in actual life.

d. Platonic constructions have the rigid character of geometrical space.

The course of development of platonic science added further character to its elements. Such additional character is ***geometrical*** with (1) a characteristic of ***rigidity*** that is based on ***invariant symmetries***, namely, the structure of homogeneity and isotropy introduced above; and (2) a characteristic of ***continuity*** that is also grounded in invariance. Plato's Ideas incorporated such rigidity and continuity; modern physics is built around mathematical "spaces" that maintain them.

Using de Santillana as a chief guide, it appears that the geometrical character of platonic constructions had two main sources, Pythagoras and Parmenides.

Pythagoras (c. 550 B.C.E.), perhaps-legendary founder of a cult, is credited with famous discoveries in geometry and harmony. He reportedly unified them with reincarnation, astronomy, rhythm and arithmetic. He taught that Number was the *eidos* (form) and *logos* (proportion) behind all such things. ***Proportion*** was a chief structural principle of Pythagorean thought. In music theory, an important focus of such thought, a system of proportional relations organized the different sizes of strings and tubes in musical instruments and the corresponding musical tones. "Pythagorean harmonics" state specific proportions or ratios of numbers.

"What they were inventing was a 'geometry of numbers' or arithmogeometry of a rather fanciful kind. It served to express their original idea of proportion as underlying everything. If 'proportion' comes to take such a vast importance in Greek thought, it is largely due to the undefined mass of significance contained in its name. *Logos* means 'discourse,' 'reason,' 'argument,' 'inference,' and also 'proportion.' " (65.)

In Pythagorean thought, "reality is made of things which oppose each other" and oppositions are resolved through "*harmonia*, which is the old word for the tension between opposites. The mean proportionals do more than articulate the intervals; they are held to be the actual bond or *fastening* which holds together the disparate or unrelated elements of reality and welds them into a whole. All of Pythagorean and Platonic physics rests on that certainty." (67, emphasis in original.)

According to de Santillana, the "dreamy enterprise" of Pythagoras led to "the theory of conic sections, which allowed Kepler and Newton to conquer the universe." (67.) As discussed below, modern physics continues to teach that a supposed texture of proportional fastenings "holds together the disparate or unrelated elements of reality and welds them into a whole."

Pythagoreans had a visionary cosmology based on music, numbers and geometry. The vision was extended by Parmenides of Elea (c. 500 B.C.E.), "who first among the Pythagoreans taught the sphericity of the Earth, and that the moon shines by reflected light." (89.)

"Parmenides is the one person of whom Socrates speaks with marked reverence, describing him in Homeric terms as 'august and terrible in his greatness.' … Thus, by way of Plato, Parmenides is enshrined in the realm of pure philosophy, as the First Metaphysician." (94-95.)

"He wrote only one work, entitled *On Nature* ... a poem, in oracular and cryptic style, probably in the tradition of the lost Pythagorean 'Sacred Discourses.' " (89.) *On Nature* has two parts structured like Plato's divided metaphysical line discussed above, titled in Parmenides' case "The Way of Truth" and "The Way of Opinion." (*Id*.)

"Parmenides, one of Plato's predecessors who influenced him greatly, had taught that the pure knowledge of reason, as opposed to the delusive opinion of experience, could have as its object only a world which did not change, and that the pure knowledge of reason did in fact reveal such a world." (Popper, *Open Society,* 31.)

De Santillana offers translations of Parmenidean fragments that he interprets through a puzzle that I call "what is Being?" That is, Parmenides teaches the supremacy of "Being." In the puzzle form suggested by de Santillana, "Being" is something you know; it is described in terms of its features but it is not named exactly. The puzzle is to name it exactly.

Parmenides wrote: "Being is uncreated and indestructible, one all through, whole, immovable, and without end. It never was, nor is it ever going to be; for it exists now, all together, a single continuum. … Moreover, it is immovable in the bonds of mighty chains, without beginning and without end. … Remaining in the same, in the selfsame place, it abides in itself. And thus it remains steady in its place; for strong Necessity keeps it in the bonds of the limit that constrains it round. … But since the last bound is defined on all sides, like a well-rounded sphere, it is equally poised from the center in all directions; for it is necessary that it should not be greater in one direction and smaller in another." (91-92.)

de Santillana proposes a solution to the puzzle (95, emphases added):

"If we accept the word 'Being' not as a mysterious verbal power, but as a technical term for something the thinker has in mind but could not yet define, and replace it by *x* in the context of his argument, it will be easy to see that there is one, and only one, other concept which can be put in the place of *x* without engendering contradiction at any point, and that concept is ***geometrical space itself***… Moreover, it is built up step by step, with the use of the ***principle of indifference or sufficient reason***, that we have seen used by Parmenides' naturalist predecessors; it is here for first time applied consciously as a fundamental instrument of scientific logic."

"Geometry as the Greeks meant it put three requirements on its space: first, it must have continuity…second, it must be the same, homogeneous throughout, so that we can move figures freely from place to place without altering their geometrical properties; and finally, it must be isotropic or the same in all directions." (95.)

"The true conception of geometrical space, once formed, is equally well adapted to serve as a substratum for physical form, in view of its rigidity and impassability." (97.)

de Santillana's "rigidity" denotes invariance that combines homogeneity and isotropy. In constructions of "classical mechanics," massive bodies are often said to be rigid in a similar way. Quantum mechanics constructs rigid collections of states organized into particles. In contrast, actual material bodies are rarely rigid and often have characters that respond to forces in complex ways. A ribbon of leather is softer than a ribbon of steel; but most leathers can bend repeatedly while steel typically fractures after a few sharp bends. Leather is soft and tough; steel is hard and brittle. Such individual characters of actual materials do not fit into rigid forms.

Like original platonic constructions, spatial constructions in modern science are subject to rules of invariant symmetry and continuity. Unfortunately for scientific claims to universality, actual material bodies such as steel and water, and, I suggest, brains, go through transformations during which symmetry breaks in a variety of discontinuous ways that do not follow rules of invariance.

Suppose a geometrical figure, e.g., a circle, is represented by an elastic black thread glued onto the elastic surface of a blue balloon. Consider the possibility of deforming that surface by stretching (inflating the balloon), or by bending or twisting. Consider the fate of the geometrical figure when space is deformed. Look for deformations that conserve geometrical figures. Because of the character of space, the only deformation that will clearly preserve geometrical figures is a ***system of organized proportional changes*** of lengths that maintains both homogeneity and isotropy at every point in the deformation. Such changes occur during uniform inflation and deflation of a perfectly spherical balloon: figures drawn on the surface of such a balloon are conserved through the changes. When proportional changes of lengths are so organized, space is homogeneous and isotropic at every point and at every instant during such a deformation. The proportions themselves are maintained as "invariants" during the changes.

In other words, proportions are maintained as invariants if all subdivisions of geometrical space change together in an organized way. Then, proportional relations make up invariant structures. This is what is meant by the "rigidity" of space. Space makes up one whole thing and it is not possible to change any piece independently. Form-conservation requires that overall features change in a specific continuous organized way. Parmenides' language expresses these facts.

Temporal forms can have a rigid character comparable to that of space or, alternatively, they can have a flexible character that is incongruent with that of space. An example of relative rigidity in temporal forms occurs when an orchestra is led by a conductor who controls the tempo; all musicians in the orchestra "uniformly" follow the tempo set by the conductor — all speed up or slow down together. An example of more flexible temporal forms is that of a person chopping vegetables while conversing with a friend sitting in the kitchen; the tempo of chopping and the tempo of conversation are independent and each may vary without regard for the other. A more complex example of flexible temporal forms is that of a footrace, discussed below, where a runner's tempo of muscular movements is subject to personal efforts.

Imagery of deforming geometrical figures also illustrates the characteristic of ***continuity*** in spatial forms and, by way of contrast, also illustrates discontinuous transformations in temporal forms. Suppose a spherical balloon is cyclically inflating and deflating. Geometrical figures drawn on the surface are maintained during inflation and deflation, showing a conservation principle. It is never the case, for example, that, at some point during the inflation part of the cycle, a circle suddenly changes into a triangle. The conservation of the figure during inflation stands in contrast to temporal forms that undergo discontinuous transformations that are observed in many activities, e.g., dialogues, the changing gaits of a horse that increases speed and episodic balancing forms that govern contests.

4. Modern versions of platonic science construct imaginary domains in which particles, objects, events and changes are controlled by eternal, universal Laws of Physics. Such Laws would impose invariant symmetries of empty space on material bodies; but they fail to describe or control actual transformational changes that occur during a fast quench of red-hot steel or during the growth of crystalline snowflakes in a cloud of water vapor.

a. Modern platonic science has advocates and alternatives.

I offer views of modern physics that differ in content and approach from prevalent positions that some call "the modern scientific view" and that I call "platonic science." My views are directed towards development of new technologies and have a revisionary purpose.

Richard P. Feynman advocated platonism in *The Character of Physical Law* (1965), quoted above. The text came from Feynman's Messenger Lectures at Cornell University presented in 1964 to a lay audience. This was the same period as the famous *Feynman Lectures on Physics*; those in Vol. I were given to first-year students at Cal Tech. *The Character of Physical Law* and *The Feynman Lectures*, Vol. I, chaps. 1 – 4 state an exemplary platonic view. In such a view, Laws of Physics describe and control everything in the Universe.

Of course, not all scientists are platonists. Nobelist P. W. Bridgman set forth an "operational" view in *The Nature of Physical Theory* (1936), which contrasts neatly with Feynman's *The Character of Physical Law*. More views are provided by Truesdell (rigorist) and Feyerabend (anarchist). My impression is that many scientists abstain from such views altogether. In the field of scientific psychology and brain models, however, platonism has a dominant influence. As discussed below, an alternative approach seeks to overcome limitations of platonic science.

As a first critique, I suspect that few chemists would concur with Feynman's statements (*Lectures*, § 3-2, Chemistry) about rules that state "which substance is combined with which, and how, that constituted inorganic chemistry. All these rules were ultimately explained in principle by quantum mechanics, so that theoretical chemistry is in fact physics. … substances which are associated with living things…are just the same as substances made in inorganic chemistry but more complicated arrangements of atoms are involved…physical chemistry and quantum mechanics can be applied to organic as well as to inorganic compounds."

Linus Pauling (1901-1994) was Feynman's colleague at Cal Tech and a pioneer in both inorganic and organic chemistry. Pauling used quantum mechanics extensively in his own work. In his 1954 Nobel Laureate Lecture, Pauling stated: "The development of the theory of molecular structure and the nature of the chemical bond during the past twenty-five years has been in considerable part empirical - based upon the facts of chemistry - but with the interpretation of these facts greatly influenced by quantum mechanical principles and concepts." Such a statement is quite different from implying, as Feynman does, that facts of inorganic chemistry are "rules" that are "explained in principle by quantum mechanics" and that "the same" approach applies to organic chemistry. It is the difference between a scientist who uses principles of quantum mechanics to construct tools for fact-based investigations and one who declares that quantum mechanics explains in principle everything in the Universe.

Differences are further illustrated by Pauling's description of his "arbitrary" resonance theory that uses cycles of static images, which are "idealized, hypothetical structural elements." "In the description of the theory of resonance in chemistry there has been a perhaps unnecessarily strong emphasis on its arbitrary character. … It might be possible to develop an alternative simple way of discussing the structure of the amide group, for example, that would have permitted chemists to predict its properties, such as planarity; but in fact no simple way of discussing this group other than the way given above, involving resonance between two valence-bond structures, has been discovered, The convenience and usefulness of the concept of resonance in the discussion of chemical problems are so great as to make the disadvantage of the element of arbitrariness of little significance. Also, it must not be forgotten that the element of arbitrariness occurs in essentially the same way in the simple structure theory of organic chemistry as in the theory of resonance - there is the same use of idealized, hypothetical structural elements. … Chemists have found that the simple structure theory of organic chemistry and also the resonance theory are valuable, despite their use of idealizations and their arbitrary character."

It appears that Pauling devised and developed explanations that were criticized because they were outside and beyond "rules" that are "explained in principle by quantum mechanics."

Feynman began *The Character of Physical Law* with "The Law of Gravitation, an example of Physical Law." "Why I chose gravity I do not know. … Modern science is exactly in the same tradition as the discoveries of the Law of Gravitation." (14.) I suggest that platonic science has had its greatest successes with gravitation because such matters are grounded in empty space.

According to Feynman, "great general principles which all the laws seem to follow" include "the great conservation principles." (*Id*., Chap. 3.) In brief, a conservation principle applies to a system that is undergoing changes. A certain quantity is conserved: "the number does not change" while changes are occurring around it. For example, movements of billiard balls on a table and of particles in an evacuated chamber follow principles of conservation of momentum, conservation of angular momentum and conservation of energy. Such mechanical constants of motion are used to calculate and predict actual motions of billiard balls and particles.

An important principle of modern physics connects symmetries to conservation laws. Accordingly, conservation of momentum is based on spatial homogeneity, previously discussed in connection with platonism. Conservation of angular momentum is similarly based on spatial isotropy. (103.)

In other words, invariant relations of spatial homogeneity and isotropy that gave space its rigidity in prior platonic constructions are expressed as conservation of momentum and conservation of angular momentum in constructions of modern science.

Such rigidity means that invariant relations are binding at every location and at every moment and throughout eternity. "Physicists as a rule hold that the physical laws are eternal. (There are exceptions, such as physicists Paul Dirac and John Archibald Wheeler …) It is indeed difficult to think otherwise, since what we call laws of physics are the results of our search for invariants." (Popper & Eccles at 14.)

"To … our list of conservation laws…, we can add energy. It is conserved perfectly as far as we know." (Feynman, *Character of Physical Law* at 77.) Feynman apparently claims victory in the face of serious challenges: "Of all the conservation laws, that dealing with energy is the most difficult and abstract, and yet the most useful." (68.)

My critical reconstruction challenges the claim of "perfect" energy conservation. I suggest that there are phenomena — especially discontinuous transformations in material bodies driven by sudden changes in surroundings — where the principle of energy conservation does not apply in the hegemonic way presumed by platonic science. Chief examples discussed below are red-hot steel being quenched in ice water and production of snowflakes from gaseous water vapor. The principle of energy conservation requires "state" conditions, e.g., a defined and uniform "temperature" and static surroundings. However, there is no defined "temperature" in the examples. Instead, hot surroundings are changing to cold and energy is suddenly dissipated. The results are material bodies with distinct and individual characters, e.g., snowflakes.

Feynman had some good reasons for claims about "perfect" energy conservation. The goal of comprehending physical phenomena through invariance, symmetry and continuity did succeed in important cases. However, such successes are set in empty space and in situations that are based on empty space. Scientific reasoning based on empty space started off in ancient Greece with geometrical reasoning and developed historically from that base. Structural components of geometrical reasoning such as axioms and theorems guided early philosophers and scientists. Newton's *Principia Mathematica* (1687), used geometrical proofs rather than calculus derivations like those taught today. He evidently thought that geometrical proofs were more authoritative than his novel mathematics. Newton's approach requires the mathematical reduction of huge solar and planetary masses to geometrical "mass points" or "corpuscles" and such a reduction was a point of difficulty for him. Strictly applied, such a reduction is limited to symmetrical bodies. Although celestial bodies are approximately spherical, there are deviations. The entire approach becomes problematical when complications are introduced. "Three-body problems" became evident during the 18th century. "Chaos" conditions in possible orbits were disclosed when computers became powerful enough to handle massive calculations required to apply Newton's formulae to an actual planetary system.

Major events in the saga of development of electricity and magnetism also occurred in empty space. Investigations into material phenomena such as Faraday's development of electro-chemistry did not figure in the main line of the saga that culminated in Maxwell's spectacularly successful achievements. Maxwell used empty space symmetries, conservation principles and continuity assumptions to construct his "displacement current" and the "light is Electromagnetic Waves" model. He stated the speed of light in terms of electrical and magnetic quantities, revealing long-sought secrets. Later, Einstein's theories superseded both Newton's and Maxwell's models but retained and developed their spatial approach. "Elementary particle physics" – where Feynman was eminent – treats empty space as definitive for all situations.

Disregarding the limited empty space basis of his claims, Feynman declares that broader platonic goals have already been achieved: "With these particles that I have listed, all of the low energy phenomena, in fact all ordinary phenomena that happen everywhere in the Universe, so far as we know, can be explained. … For example, life itself is supposedly understandable in principle from the movements of atoms, and those atoms are made out of neutrons, protons and electrons. I must immediately say that when we state that we understand it in principle, we only mean that we think that, if we could figure everything out, we would find that there is nothing new in physics which needs to be discovered in order to understand the phenomena of life. … In fact, I can say that in the range of phenomena today, so far as I know there are no phenomena that we are sure cannot be explained this way, or even that there is deep mystery about." (151.)

Different views are noted by Popper & Eccles at 544: "Eugene Wigner ["Are We Machines?" 1969] has demonstrated the fallacy in postulating 'that life is a physicochemical process which can be explained on the basis of ordinary laws of physics and chemistry.' He goes on the predict that 'in order to deal with the phenomenon of life, the laws of physics will have to be changed, not only reinterpreted.' "

Feynman also taught that the most important scientific "fact" is that "all things are made of atoms." (Lectures I-1-2.)

A different view as to this proposition was stated by Truesdell & Noll (1): "Matter is commonly found in the form of materials. Analytical mechanics turned its back upon this fact, creating the centrally useful but abstract concepts of the mass point and the rigid body, in which matter manifests itself only through its inertia, independent of its constitution; 'modern' physics likewise turns its back, since it concerns solely the small particles of matter, declining to face the problem of how a specimen made up of small particles of matter will behave in the typical circumstances in which we meet it. Materials, however, continue to furnish the masses of matter we see and use from day to day: air, water, earth, flesh, wood, stone, steel, concrete, glass, rubber..."

As discussed below, "analytical mechanics" fails to connect to actual life. Animal bodies are neither mass points nor rigid. Animal bodies are always dissipating energy and never come to equilibrium, even in sleep. Animal bodies act on their own in ways that are not controlled by reason. Analytical mechanics, e.g., statistical mechanics, turns its back on such facts.

Thermodynamics is the branch of physics that deals with changes in material bodies in general. Specific topics in ***materials science*** deal with classes of materials, e.g., metals, semiconductors, ceramics. Truesdell (Rational Thermodynamics, 1) contrasts models of thermodynamics with "mathematical theories of mechanics" that have progressively become "more precise, briefer, easier to learn, and more widely applicable." "Thermodynamics has had a different history. It began out of steam tables, venous bleeding, and speculations about the universe, and has always had a hard time striking a mean between these extremes. While its claims are grandiose, its applications are usually trivial. The classical illustrations all concern systems which from the standpoint of mechanics are so special as to be degenerate, yet thermodynamicists are prone to claim that their science somehow implies mechanics as a corollary." (*Id*.)

Truesdell seeks to "show you that classical thermodynamics can be stated precisely and learned, just as classical mechanics is stated precisely and learned." (*Id*., 4.) His method is to limit the class of bodies to which thermodynamics is applied, through requirements that bodies have certain "constitutive relations." Precision in Truesdell's thermodynamics is achieved at the cost of "universality." The class of bodies defined by such relations is highly limited. For example, bodies with memories are excluded from the class.

My revisionary view of physics differs from those of both Feynman and Truesdell. (See *A Patchwork Of Limits* (2000) available on my website.) In my view, physics models are human inventions and are only partially supported by an underlying "reality." In contrast to those who envision total support, I suggest that models do not cohere into a Grand Unified Theory and that models do not "emerge" from each other. Each model is free-standing and has a limited domain of application. Conscientious scientists define such limits at the outset of the model. In my view, there are important differences between models of gravity, mechanics, electromagnetism and thermodynamics. Different models apply to different phenomena and use different methods.

For me, "thermodynamics" means "energy conversion" with various meanings for "energy" and "conversion" and with various mathematical and/or device models. Energy flows are always dissipative but dissipation can be controlled in some situations and energy can be conserved in storage bodies, e.g., using chemical bonds. Living animal organisms combine dissipative processes with storage bodies and control their own movements through adjustable processes.

“Conservation of energy,” a pillar of platonic science, differs from conservation of momentum because energy conservation in material bodies is imposed through time-invariant equilibrium constraints and by means of what Truesdell calls “constitutive relations” or “constitutive laws” that depend on the situation and on particular properties of materials; while the stronger momentum conservation law is grounded in homogeneity of empty space. “That is, the ‘first and second laws’ are to be interpreted, not as restrictions on the processes a body must undergo, but as restrictions on the response of the body itself.” Truesdell, *Rational Thermodynamics* at 13. In other words, the first law of thermodynamics, “conservation of energy,” is based on the particular constitution of the body and on the situations in which tests are conducted rather than being an inherent feature of the Universe. As discussed below, an actual body of water that changes from liquid to gas to solid, is not described or controlled by what we know as Laws of Physics during the formation of snowflakes.

Mechanics based on Newton’s Laws, also known as “classical mechanics” (Goldstein), occupies one domain of investigations into energy. Electromagnetism and electrical engineering occupy another domain. Attempts to unify the two domains (classical mechanics and electromagnetism) with thermodynamics have led to “differences of opinion regarding the force in electromagnetic bodies.” (Penfield & Haus at 234.) Possible reasons for controversies include: “First, the problem requires concepts from several fields that are ordinarily considered to be distinct. Thus, one must simultaneously deal with continuum mechanics, thermodynamics, electromagnetism, and special relativity. This interdisciplinary aspect makes the problem difficult to study. ¶ Second, in many cases the force cannot be verified experimentally in detail… ¶ Third, previous efforts to derive force expressions were primarily for material that was electrically and magnetically linear. … Thus it is difficult to say which results depend upon the linearity of the material and which are more fundamental.” (*Id*. at 234-235.) Such difficulties are typical of those encountered in scientific investigations of material phenomena.

b. Minkowski’s “union of space and time” illustrates puzzling claims of conceptual hegemony.

In a famous 1908 address, “Space and Time,” H. Minkowski claimed that “radical” new theories of Lorentz and Einstein resulted in “changed ideas of space and time.” He predicted: “Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.”

Minkowski’s claims are no longer novel. A leading cosmologist writes that “…relativity…has revolutionized our ideas of space and time.” There is “a four-dimensional space called space-time.” (Hawking, *A Brief History of Time: From the Big Bang to Black Holes* (1988) at 21, 24.)

Such claims remain puzzling. Chiefly, such a union fails to incorporate or connect to actual distinctions between space and time. From a perspective of actual life, I have an experience of the character of space that is very different from that which I have of time. I move about freely in space, including movements that repeat or that cyclically go away and come home, to and fro. In contrast, I cannot move around in time; rather time inexorably moves me towards the mortal end shared by all creatures. Unlike fixed goals in space, my purposes projected into the future are always shifting and changing.

The principle of sufficient reason, discussed above, suggests that a metaphysical domain should be constructed according to principles of maximum symmetry. Symmetry is inherent in space according to principles of homogeneity and isotropy. Relativistic principles modify descriptions of spatial symmetries but do not change their application or significance.

Symmetry comparable to spatial symmetry is not present in time because of the "arrow of time." This common phrase stands for the fact that all actual changes share a specific direction that begins in the past and that moves into the future.

According to platonic science, future and past have "the same" character. The trajectory of a particle has an exact and fixed course as it starts traveling, while it is traveling and after it has traveled. In primal platonic constructions, time can be reversed without altering the results.

An illuminating statement of principles by neuroscientist Gerald Edelman in *Bright Air, Brilliant Fire* (at p. 202) implicitly identifies focal differences between platonic time and actual time.

> Thus we arrive at one of the grand themes of physics *There is a deep connection between conservation laws and symmetry*. Empty space and time are symmetric; that is, they appear the same under many kinds of change. Space is the same regardless of translations, rotations and changes in direction. When reversed, time is the same in either direction (I mean the time of the physicists, not your own personal sense of time.) …
>
> Without the application of a force, a body or a particle will not alter its velocity and direction of its motion (its momentum) or its energy. The German mathematician Emmy Noether first showed that the conservation of these quantities can be *formally* identified with symmetry principles. For example, the conservation of momentum corresponds to the symmetry of space under translation. The conservation of angular momentum corresponds to the symmetry of space under rotation. The conservation of energy corresponds to the symmetry of time under reversal of direction. (Time reversal cannot actually be carried out, but the physical laws can be checked for their invariance under such operations.)

In actual life, future and past are different. In the future lie many variable possibilities while the past has only a single fixed actuality. In the momentary present focus of "now," many possible movements change into a single actual movement. The homogeneous and isotropic "sameness" that extends uniformly throughout space regardless of a person's place in it is absent in time. In actual life, for each person, a moving, elastic "now" divides conjectural future from unchangeable past; now, past and future have different characters.

Events are ***actually ordered*** in time. That is, in actual life, events occur one after another in a dependent way. As a matter of brute fact, "before" and "after" are of foundational importance. Such ordering is not inherent in space; rather, order in space is established by imposing a system of coordinates such as Cartesian coordinates x, y and z. The "sides" left and right are defined by convention and can sustain mirror images, "the same" as to every detail.

Flows in time cannot be reversed except in imagination and such imaginary time reversals do not connect to actual life. According to the traditional formulation, it is impossible to put an egg (e.g., Humpty-Dumpty) together again after it is broken. The word ***irreversible*** is used to specify changes where a return to a previous condition is impossible. Conversely, changes where the initial position can be recovered, or apparently so, are ***reversible***. In the actual world, all changes are irreversible. There are "approximately" reversible events, e.g., in videogames and movements to and fro — but even these events occur at different times in a changing world and may be thwarted by irreversible events such as breakages or death.

Irreversible changes occur in actual life when hot steel is quenched, when snowflakes form in a laboratory and during sports competitions and trials in court. Each of these events is carried out intentionally to produce such irreversible changes. I suggest that irreversible events are the normal or default kind of event in actual life and that apparently reversible events are special, e.g., like winning a rare reversal in a court case. In contrast, imagery of platonic science teaches that reversible events add up to irreversible events.

In sum, as to the character of time, actual life clashes with platonic science. Notwithstanding clashes between platonic imagery and actual life, some scientists claim hegemony for platonic constructions. Instead of dealing with issues, they brandish authority and invoke metaphysical constructions. For example, Hawking argues that concepts of "entropy" and "disorder" support his arguments about a "thermodynamic arrow of time," a "psychological arrow of time" and a "cosmological arrow of time" that "point in the same direction [when] conditions are suitable for the development of intelligent beings." (145.) "Disorder increases with time because we measure time in the direction in which disorder increases. You can't have a safer bet that that!" The bet is bolstered by a belief that brains are computers: "Just as a computer, we must remember things in the order in which entropy increases." (147.)

Fallacies in such arguments are discussed below. Contrary to Hawking's safe bet, "entropy increases" occur during repetitive muscular movements, which can be highly ordered activity even though it is not the "equilibrium" kind of order that Hawking's imagery requires. Repetitive muscular movements can build a wall out of a heap of bricks: as time passes and entropy increases, more order appears. The concept of entropy was invented by Rudolf Clausius (1822-1888) and has only limited and specific applications. Clausius' entropy applies to bags of an ideal gas that are "relaxing towards equilibrium" but not to purposeful muscular movements.

Statistical mechanics, developed by Ludwig Boltzmann (1844-1906) and Josiah Willard Gibbs (1839-1903) and a source of "entropy is information" notions, strictly applies only to static systems, but it also has quasi-static extensions. As discussed below, such concepts do not apply to discontinuous transformations that produce individualized snowflakes. Nor, I suggest, do they apply to transformational activity of a brain that is burning through a lot of sugar energy. The human brain consumes some 20% of the entire body's supply of energy. In a highly dissipative system like a brain, entropy always increases. Entropy is increasing regardless of whether activities grow more ordered or more disordered. Entropy increases do not control order.

Cosmological claims about entropy, such as those of Hawking, are empty. They do not answer questions about the clash between Minkowski's views and the facts of actual life. Minkowski's prediction that "space by itself, and time by itself are doomed to fade away" has proved to be erroneous. Only physics buffs and professionals speak of a "union of the two" — but all persons, including physicists, continue to use clocks without reference to meter sticks. What remains puzzling to me is the widespread belief that Minkowski's claim and prediction about a "union" of space and time have some truth or validity that is superior to my experience of actual life.

c. Reconstructing time into a kind of space makes time fit the primal linear form of platonic science.

I focus on the ***linear form*** that is the ***primal form of platonic science***. The linear form appears in different guises in different sciences and technologies and with various symbols and applications. The point of origin of linear forms is the formula: distance = rate × time or d = r×t. An historical example of the linear form was ***Hooke's law for an elastic spring***, formalized as F = –k×x. Another elementary example is ***Ohm's law of electrical resistance***, V = I×R.

Hooke's law and Ohm's law are examples of constitutive laws, mentioned above, and are based on properties of materials that exist only for certain ranges of activity. Such laws fail for spring stretching or electrical currents greater than a certain amount, which depends on the material of the actual spring or the actual resistor. In general, I suggest that platonic forms are limited in practical applications to ranges of activity determined by properties of actual materials.

As the name indicates, a linear form is based on the form of a geometrical line. The form for a line in analytic geometry is y=a×x+b; a simplified form for a line is y= a×x. Then the line passes through the origin or center of the graph.

Minkowski's union of space and time is expressed by a ***linear transformation.*** Linear transformations are the chief form of transformation studied in platonic science. Other linear forms in platonic science include linear approximations, linear spaces and linear functions.

The ***geometrical linear transformation*** exemplar set forth below is used in a space of 3 dimensions where there are 2 fixed perspectives, the X perspective and the Y perspective. X and Y are sitting together but facing in different directions. An object that X sees as "straight ahead" is off to one side for Y.

The symbols (x_1, x_2, x_3) specify a point seen from the X perspective; and the symbols (y_1, y_2, y_3) specify the same point seen from the Y perspective. The relationship between the two perspectives is specified by the set of symbols (a_{11}, a_{12}, a_{13}, a_{12}, a_{22}, a_{23}, a_{31}, a_{32}, a_{33}).

$$y_1 = a_{11}\times x_1 + a_{12}\times x_2 + a_{13}\times x_3$$

$$y_2 = a_{21}\times x_1 + a_{22}\times x_2 + a_{23}\times x_3$$

$$y_3 = a_{31}\times x_1 + a_{32}\times x_2 + a_{33}\times x_3$$

In such a geometrical linear transformation, the symbols (y_1, y_2, y_3) and (x_1, x_2, x_3) stand for ***variable*** quantities. The symbols (a_{11}, a_{12}, a_{13}, a_{12}, a_{22}, a_{23}, a_{31}, a_{32}, a_{33}) stand for ***fixed*** quantities. I suggest that such a transformation is an exemplar of platonic forms in that the fixed symbols (a_{11}, a_{12}, a_{13}, a_{12}, a_{22}, a_{23}, a_{31}, a_{32}, a_{33}) stand for the ***structured proportionals*** of Pythagoras and Parmenides that characterize the rigidity of geometrical space. There is a "space" defined by the set of equations that exactly matches geometrical space. In this system, isotropy appears as fixed relations involving the (a_{11}, a_{12}, a_{13}, a_{12}, a_{22}, a_{23}, a_{31}, a_{32}, a_{33}). Homogeneity can also be shown but more complex discussions are required that are based on the y=a×x+b form for a line.

Linear forms have advantages that make them suitable for science and technology. Such forms combine and coordinate fixed features (a_{ij}) and variable features (x_j and y_i). Easy arithmetic operations + and × make up a convenient computational device. The linear transformation is developed into groups of linear transformations organized by means of "linear algebra."

In their advances, Lorentz, Einstein and Minkowski conceived of X and Y arranged as before but also as traveling at a steady velocity with respect to each and matching for an instant at t = 0 = t', x = 0 = x', y = 0 = y' and z = 0 = z'. They employed an expanded form of the geometrical linear transformation:

$$y_1 = a_{11}\times x_1 + a_{12}\times x_2 + a_{13}\times x_3 + a_{14}\times t$$
$$y_2 = a_{21}\times x_1 + a_{22}\times x_2 + a_{23}\times x_3 + a_{24}\times t$$
$$y_3 = a_{31}\times x_1 + a_{32}\times x_2 + a_{33}\times x_3 + a_{34}\times t$$
$$t' = a_{41}\times x_1 + a_{42}\times x_2 + a_{43}\times x_3 + a_{44}\times t$$

New variables t and t' were made a part of the form. The variable quantity t' stands for the time of an event in the Y perspective, along with the quantities (y_1, y_2, y_3) that specify the event position. Similarly, t and (x_1, x_2, x_3) specify the time and position of the same event in the X perspective. Specific values of the fixed symbols (a_{11}, a_{12}, a_{13}, a_{14}, a_{12}, a_{22}, a_{23}, a_{24}, a_{31}, a_{32}, a_{33}, a_{34}, a_{41}, a_{42}, a_{43}, a_{44}) depend on the velocity between X and Y and are set forth in the well-known Lorentz transformation. At t=0, the new form reduces to the prior form.

The Lorentz transformation has the effect of turning time into a spatial variable and making time part of a rigid system of proportional relations. The system is not entirely rigid because the fixed symbols (a_{11}, a_{12}, a_{13}, a_{14}, a_{12}, a_{22}, a_{23}, a_{24}, a_{31}, a_{32}, a_{33} a_{34}, a_{41}, a_{42}, a_{43}, a_{44}) have a dependence on the velocity between X and Y and such speed can change. In applications of the Lorentz transformation, however, the velocity is typically held fixed and values for a_{jk} remain fixed like fixed proportionals of the Pythagoreans. Changing velocities can be based on such fixed forms.

Spatialized time is certainly useful for some purposes, such as purposes motivating Lorentz, Einstein and Minkowski. A chief purpose was to describe Electromagnetic Waves traveling in empty space. Some electromagnetic waves are cyclically invariant phenomena. Imagery of a "traveling electromagnetic wave" uses a repetitive mathematical sine function. An imaginary infinite sine wave repeats in empty space and in time, thus in boundless eternity.

If the activity that needs to be described is Electromagnetic Waves traveling in empty space, spatialized time is suited to the task. Spatialized time is also suitable for other purposes, including a re-worked version of Newton's Mechanics for "corpuscles" and for the class of situations specified in Einstein's Special Theory of Relativity of 1905: "kinematics of the rigid body … relationships between rigid bodies (systems of co-ordinates), clocks and electromagnetic processes." (Einstein, Special Theory, 38.) Spatialized time has solid domains of application in empty space, Electromagnetic Waves, corpuscles and rigid bodies.

In 1916, Einstein published the General Theory that further developed space and time relations. In the previous system, it was the rule that: "To two selected material points of a rigid stationary body there always corresponds a distance of quite definite length, which is independent of the locality and orientation of the body, and is also independent of the time." A similar independence with respect to locality, orientation and time applied to an interval of time measured by a stationary clock. In contrast, "the general theory of relativity cannot adhere to this simple physical interpretation of space and time." (Einstein, General Theory, 112.)

Proceeding from the previous "geometrical linear transformation" form, development leads to the following form, a ***differential linear transformation*** form. Metaphorically, steps taken by

Einstein in moving from the special theory to the general theory are reflected in steps from the previous geometrical linear transformation to the new differential linear transformation. The bold-faced symbol "**x**" stands for x_1, x_2, x_3.

$$dy_1 = a_{11}(\mathbf{x}, t) \times dx_1 + a_{12}(\mathbf{x}, t) \times dx_2 + a_{13}(\mathbf{x}, t) \times dx_3 + a_{14}(\mathbf{x}, t) \times dt$$

$$dy_2 = a_{21}(\mathbf{x}, t) \times dx_1 + a_{22}(\mathbf{x}, t) \times dx_2 + a_{23}(\mathbf{x}, t) \times dx_3 + a_{24}(\mathbf{x}, t) \times dt$$

$$dy_3 = a_{31}(\mathbf{x}, t) \times dx_1 + a_{32}(\mathbf{x}, t) \times dx_2 + a_{33}(\mathbf{x}, t) \times dx_3 + a_{34}(\mathbf{x}, t) \times dt$$

$$dt' = a_{41}(\mathbf{x}, t) \times dx_1 + a_{42}(\mathbf{x}, t) \times dx_2 + a_{43}(\mathbf{x}, t) \times dx_3 + a_{44}(\mathbf{x}, t) \times dt$$

In the new differential linear transformation form, the "d" quantities are very small quantities that can change quickly. The $a_{jk}(\mathbf{x}, t)$ are quantities that vary according to location and time but slowly in comparison to the "d" quantities. This requires that the $a_{jk}(\mathbf{x}, t)$ have the property of ***continuity*** that is central in platonic science. (Conservation is a strong kind of continuity.) The character of "space-time" is expressed by relationships among the $a_{jk}(\mathbf{x}, t)$ that are complex adaptations of the original fixed version. The new differential version "reduces" to the simpler original version if all matter is excluded from the imaginary domain.

The original geometrical linear transformation has a structure of fixed and variable elements, namely, fixed proportions and variable points. The new differential linear transformation has a similar structure of elements, namely, variable and differential quantities. Similar to the original form, the new form interweaves slowly varying proportionalized "bindings" with quick "changes" to make up a convenient and useful device. "Linear" advantages of the original form are preserved in the new, as is the spatialized character of time.

Classical physics reached culminating peaks in Einstein's theories of relativity. The Mount Sinai of Newton's Mechanics was joined through Einstein's tectonic uplifts with the Himalayas of Maxwell's Electromagnetic Equations to form a single enormous range. Cosmologists might have concluded that oceans of ignorance and uncertainty had disappeared.

Alas for cosmology, oceans were already eroding the base of the range. One oceanic current was driven by evidence of radioactive transformations. Antoine Becquerel and Pierre and Marie Curie received the 1903 Nobel Prize in Physics in recognition of their discoveries in this area.

Radioactive transformations are simple examples of discontinuous transformations. As the name indicates, during a discontinuous transformation matter undergoes a sudden and complete change of form. In a radioactive transformation, one kind of atomic nucleus changes into another kind of nucleus. Energy called "radiation" is thrown out. For example, a certain kind of hydrogen nucleus ("tritium") may suddenly change into a certain kind of helium nucleus ("helium-3"). If the disappearing hydrogen nucleus is part of a water molecule, the molecule fragments.

It is apparently impossible to predict or control when a particular tritium nucleus will undergo radioactive transformation. Such transformations occur spontaneously or "on their own." The best model is a probabilistic "Poisson process" that has a specific ***half-life***: after a time period of a half-life, half of the nuclei in a batch of identical atoms will have undergone spontaneous transformation. The half-life for the tritium radioactive transformation is 12⅓ years. Physics is unable to account for this half-life or for any radioactive half-life. In a modern physics model of the transformation, the "accurately measured β-decay lifetime of tritium ($T_{1/2}(^3H) = 12.32 \pm 0.03$ years) is used to adjust the value" of a theoretical quantity. (Simkovic *et. al.*)

In sum, platonic successes that culminated in Einstein's theories were based on empty space and developed from geometrical concepts. Time is supposedly assimilated to such spatial constructions through imposing a linear form. Some aspects of movements of and changes in matter can be approached through platonic science, such as movements of rigid bodies and corpuscles. The platonic approach fails, however, to account for other important phenomena of matter that is temporal in nature, such as half-lives of radioactive transformations. Such failures are part of larger failures of platonic hegemony to account satisfactorily for clashes between the character of time in platonic science and the character of time in actual life.

d. Thermodynamics is based on "equilibrium" that excludes multiple possibilities, that imposes invariance and that leads to linear forms.

Investigations into electromagnetism occurred in the same era as investigations into properties of matter, especially "thermal properties" of matter that are controlled by heating and cooling and by energy conversions. Maxwell, for example, made major advances in thermal physics, e.g., "kinetic theory." Some investigations into thermal properties were based on symmetries and uniformities, e.g., symmetry in crystalline materials or in a gassy material confined to a cylinder with a workable piston. Such ordered forms of matter are relatively rare in nature, although such forms do occur, e.g., in clouds of water vapor that produce snowflakes. Mostly, physical scientists use materials that are specially prepared for purposes of investigation and application. Specially prepared materials include chemical reagents and metal alloys made according to a recipe. Platonic science requires a clean work bench and complete descriptions of experiments. Through such methods invariance is proved.

Some material phenomena are rather closely modeled by platonic science but other material phenomena are evidently beyond the reach of platonic models. As discussed below, successful models of platonic science include the Ideal Gas, the Onsager Relations and a model of formation of pearlite during very slow cooling of hot steel. Platonic science fails to model the formation of martensite during very fast cooling of hot steel or the formation of snowflakes. I further suggest that platonic science fails to describe muscular movements and related feelings.

To begin with a success, the Ideal Gas Law (pV=RT) "is correct to within a few percent over a wide range of pressures and temperatures" for many gases, e.g., air and nitrogen. (Morse, 27.) It works best "in the limit of vanishingly small pressures," that is, for a very dilute gas. (Sprackling, 70.) The Ideal Gas Law applies to a unit of gas confined to an enclosed space of volume V. The "gas constant" R is a number that depends on the units that measure other quantities. E.g., R=8314 joules per degree Kelvin in one system of units. Hence, the Ideal Gas Law states a mathematical relationship between the temperature (T), pressure (p) and volume of a confined gas that is ***the same relationship*** for a class that includes many dilute gases. The ***invariance*** of the Law with respect to the class makes it a "universal law," but such "universality" is limited to a distinct class of bodies in certain distinct kinds of situations.

Another set of "universal principles" was constructed by Lars Onsager (1903-1976), who received the Nobel Prize in Chemistry in 1968 for proof of the existence of "reciprocity relations." The reciprocity relations have a linear form that resembles linear transformations discussed previously. Although the symbols in the form below resemble those shown in the geometrical linear transformation, the meaning of the symbols is closer to those of the differential linear transformation.

A form for the Onsager reciprocity relations is as follows:

$$J_1 = L_{11}\times X_1 + L_{12}\times X_2 + L_{13}\times X_3$$

$$J_2 = L_{21}\times X_1 + L_{22}\times X_2 + L_{23}\times X_3$$

$$J_3 = L_{31}\times X_1 + L_{32}\times X_2 + L_{33}\times X_3$$

The X's are a kind of "force" and the J's are a kind of "flow" or "flux" that is caused by such forces. The L's are so-called "phenomenological coefficients," meaning that values have to be measured rather than derived from principles, similar to the "empirical" character of the half-life of tritium mentioned earlier. The general notion is that X_1 causes J_1 directly, and likewise for X_2 causing J_2 and X_3 causing J_3. To a lesser degree or indirectly, X_k also causes J_m that are different from J_k., e.g., X_1 causes J_2. Using statistical mechanics, Onsager proved that $L_{ij}=L_{ji}$, which is a ***symmetry*** that is called "reciprocity." E.g., $L_{12} = L_{21}$.

The significance of the Onsager reciprocity relations is controversial. At the the Nobel Ceremony, it was declared that "Onsager's reciprocal relations can be described as a universal natural law." (http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1968/press.html) Critics such as Truesdell disparage the achievement.

For purposes here, Onsager's formulae highlight the limited domain of application of platonic formulations. Onsager's linear formulation applies only to small deviations from the special condition known as "thermodynamic equilibrium". When a deviation from that condition becomes large, the linear form disappears, along with the reciprocity. (Kaplan *et. al.*)

Thermodynamics constructions have their own special character and limitations. In traditional imagery of "classical thermodynamics," a "homogeneous body" (having a uniform constituency) is subjected to constraints that control its activities. The body is separated from its surroundings by a "closed" boundary that effectively insulates and isolates it except for specific passages of energy and matter. Surroundings are fixed or have distinct static parts. Passages of work or energy through the boundary between body and surroundings are typically controlled through "adiabatic" or "isothermal" processes. Work performed on or by the body must be done according to calculations so that certain conditions are maintained. (Sprackling, 4-8, 10-11.) In sum, to qualify as a subject for classical thermodynamics investigations, a body must be simple, inert and highly controllable. Living animal bodies are not so qualified.

In thermodynamics, a chief focus is on the temperature of the body. Suppose we consider simple bodies such as a flask of water or a piece of metal alloy. There are various possibilities for the temperature. Perhaps one temperature applies to the whole body or perhaps there are different temperatures at different places in the body. Smooth and orderly differences in temperature can be described by temperature gradients. An underlying question is whether temperature can always be defined or whether there are situations where a temperature cannot be defined.

Of paramount importance is the restriction of the First and Second Laws of Thermodynamics to bodies ***in equilibrium*** or "close to equilibrium." Equilibrium means that the temperature is "the same" throughout the entire body and remains "the same" indefinitely. Changes are caused by external influence and the body never acts on its own. It is only when the body is in equilibrium that temperature questions are easily answered. I suggest that a body in equilibrium has a certain symmetry that enables practitioners of platonic science to construct Laws. In the absence of equilibrium, perhaps the Laws do not apply.

“Classical thermodynamics only deals with *equilibrium states* of a system…These equilibrium states are reached by letting the system settle down long enough so that quantities such as temperature and pressure become uniform throughout, so that the system has a chance to forget its past history, so to speak.” (Morse, 7, emphasis in original.)

“In a sense, the reason that classical thermodynamics is usually limited to a study of equilibrium states is because an equilibrium state is the state in which heat energy can easily and unmistakably be distinguished from mechanical energy. Before equilibrium is reached, sound waves or turbulence may be present, and it is difficult to decide when such motion ceases to be ‘mechanical’ and becomes ‘thermal.’ ” (*Id*., 13.)

“To put it in other language, although the gas may start in a state of turbulence, if it is left alone long enough internal friction will bring it to that state of thermodynamic quiescence we call *equilibrium*, where it will remain.” (*Id*., 6, emphasis in original.)

I suggest that “equilibrium” in classical thermodynamics establishes uniformity and “time invariance” that parallels previously-discussed spatial invariance. In an equilibrium state, each moment is identical to each other moment. That is, in imagination and using spatialized time, the system can be lifted out of one moment and superimposed onto another moment and the systems are indistinguishable for purposes of the science. Such superimposition is comparable to the imaginary superimposition of figures in plane geometry.

Statistical mechanics, like that used by Onsager, provides abstract imagery. The apparent quietude of equilibrium is the result of multiple ongoing activities that balance each other in all large-scale respects. The grounding task of the scientific investigator is to put the system into such balance. The investigator then introduces an imbalance — and observes while multiple activities adjust to remove the imbalance. Adjustments are in the form of shifts in temperature or other quantities. Eventually, things quiet down so that all the multiple activities are again in balance. The investigator maintain conditions in the system while it quiets down. In sum, the system ***relaxes*** from the imbalance introduced by the investigator.

Each “X” in the Onsager Relations stands for an imbalance, the bigger the X the bigger the imbalance. Each Y stands for a flow that leads to a relaxation of the imbalance. For example, suppose that the researcher first prepares a beaker of chemical reagents and that equilibrium has been established. Then suppose that the researcher introduces changes through heating and by adding a bit of a particular chemical species without changing other conditions such as pressure and populations of other chemical species. Each imbalance causes a direct flow (temperature imbalance causes a heat flow) that relaxes and removes the imbalance. There will also be indirect flows (temperature imbalance also leads to a change in volume and re-balancing in populations of chemical species). The Onsager relations apply a geometric method of “fixed proportionals” to describe such relaxation flows.

As the Onsager reciprocity relations illustrate, platonic models of material processes typically impose invariance and prohibit alternatives. Even a very general model of thermodynamics is based on mathematical forms that are ***uniquely specified*** by state variables. That is, the “***effective principle of thermodynamic determinism***” is stated in terms of “*constitutive functionals of a thermodynamic body.”* (Truesdell, *Rational Thermodynamics* at 12, emphases in original.)

Rules of thermodynamic determinism apply to systems that are maintained in equilibrium throughout all processes. As discussed below, such rules do not apply to the fast quench used in production of martensite steel. Such rules also fail to apply to discontinuous transformations of gaseous water vapor into multitudes of different snowflakes. I suggest that such rules fail to apply to activities of brains and muscles of animal bodies such as those of human beings.

e. Quasi-static linearized forms effectively describe some slow transformations, e.g., formation of pearlite in steel-making; but such forms fail to describe similar faster transformations, e.g., formation of martensite during a fast quench of red-hot steel.

The content of platonic science is constituted by ***states***. In other words, in order to be admitted into the imaginary domain of a platonic science construction, a mental object must conform to certain requirements, chiefly ***invariance*** for a duration of time, whether the duration is very short (a "differential quantity") or very long ("constant of motion," "law"). Such invariance defines the "state" as a conceptual unit and provides an essential integrity, similar to the integrity of an "atom" or "particle," which are state-like units of matter. There is an implicit hierarchy in which longer-lasting states have greater influence than shorter-lasting states and in which the longest-lasting states acquire hegemonic power.

In classical thermodynamics, states are based on equilibrium. There is a simple test for equilibrium: measurements stay the same. For strict invariance, measurements cannot even be made until the body reaches an equilibrium condition. When rules are strictly enforced, the only measurements admissible are those of a body in equilibrium. Specifically, "temperature" is a term that, in a strict sense, has meaning only for a body in an equilibrium condition.

Strictly speaking, a body in equilibrium cannot change. Hence, if it stood only on equilibrium states, "thermodynamics" would have no "dynamical" part whatsoever. A study of thermodynamics that is restricted to equilibrium states is sometimes called "thermostatics." Statistical mechanics, part of thermostatics, is restricted to unchanging systems. Statistical mechanics is the chief basis of modern "entropy is information" constructions. Such constructions strictly apply only to systems in equilibrium that can never change. There are ways to work around strict requirements, e.g., models of controlled phase changes governed by the Clausius-Clapeyron relation (Feynman *Lectures*, § 45-3), but the work-arounds are also grounded in continuous maintenance of equilibrium in the body and surroundings.

A body in equilibrium "conserves energy" along with other quantities. Within certain ranges of activity, actual material bodies sometimes "conserve energy" in the form of chemical bonds, e.g., in a body of liquid fuel in a butane lighter. The converse question is more interesting, namely, whether bodies that "conserve energy" while in equilibrium will also "conserve energy" while they are being subjected to non-equilibrium processes. And, if so, which non-equilibrium processes will "conserve energy." I suggest that discontinuous transformational processes that produce martensite and snowflakes do not "conserve energy" in the strict sense. Instead, energy must be quickly drained away or dissipated. However, platonic sciences limit their investigations to bodies that "conserve energy" in the strict sense. Bodies that conserve energy in such a strict sense conform to principles of determinism. Thus, in the founding text of statistical mechanics, Gibbs defined formulations of mechanical "coordinates" p, q and a in ways that resemble the linear constructions of x, y and a discussed above.

“In the case of conservative systems, with which we shall be principally concerned, their dynamical nature is completely determined by the function which expresses the energy (ε) in terms of the *p*’s, *q*’s and *a*’s (a function supposed identical for all systems).” (Gibbs, 6)

In order to escape from eternal static equilibrium, scientists introduced a variety of methods and techniques, e.g., the quasi-static process. “When a system in an initial equilibrium state is made to change to a different equilibrium state, it is said to undergo a *process*. … at all stages of the process, the system is infinitesimally close to a state of thermodynamic equilibrium. Under this condition, each coordinate is well-defined and has a single numerical value at each instant during the process. Such a process is, effectively, a succession of equilibrium states and is termed a *quasi-static process*.” (Sprackling, 8, emphases in original.)

“To be quasi-static, a process must be carried out so slowly that gradients … are always less than infinitesimal. All real processes are, therefore, strictly non-quasi-static, but just how slowly a process must proceed to be effectively quasi-static depends on the time [] that a system needs to regain an equilibrium state…” (*Id.*)

“Classical thermodynamics deals only with equilibrium states and, therefore, can only discuss quasi-static processes, which may be regarded as limiting situations, when non-equilibrium vanishes.” (*Id.*, 9.)

I suggest that quasi-static conceptions apply to only a limited class of actual working processes. Disparaging quasi-static processes, Truesdell refers to “engineers who wish to see engines run, not creep.” (Truesdell & Bharatha, xii.) A chief advantage of quasi-static processes, from the perspective of the platonic scientist, is that they lead to linear forms.

Fortunately for pedagogical purposes, phenomena come in wide-ranging classes that show clearly how quasi-static and linear forms apply to some phenomena in the class and do not apply to other similar phenomena in the class. Such a class contains phenomena that change over a range of variation that is specified by a ***control variable***. We change the phenomenon by changing the control variable. Temperature is the simplest control variable. We control the physical condition of water by changing the temperature, turning liquid water to steam or to ice.

Three classes of phenomena show limited ranges of application of quasi-static concepts and related linear forms. In each class, some simple phenomena are described by linear models but other more complex phenomena are outside the reach of such models. The first and simplest class involves technology of audio reproduction. Designers of audio components pursue musical ideals where the desired “high fidelity” means “linear performance” and in which “nonlinear performance” is painful to the trained ear. Some high fidelity components, such as power amplifiers, operate very close to the ideal standard set by perfect linearity. Other components, such as loudspeakers, are more problematic and are, therefore, better suited for this discussion.

In a typical audio installation, the best loudspeaker performance is obtained at “low volume” when sound waves produced by the speakers have a “linear” relationship with signals in cables going to the speakers. When volume is increased past a certain level, “nonlinear performance” appears; and a cable signal carrying pure harmonic tones of a bell may lead to sound waves with ugly clumps of frequencies, just because of “nonlinearity” in operations of the loudspeaker. Turning up the volume control changes linear performance into nonlinear performance.

Another similar class of controlled phenomena is water flowing in pipes. Here, the control variable is the pressure. When the pressure driving water flow is low, water moves in a simple fashion called "laminar flow" but when pressure is high, water flow is "turbulent." "Laminar" means "layers": the idealized model treats adjacent layers as moving independently of one another. That is, laminar flow is modeled by platonic constructions that "neglect the tangential stresses altogether." (Lamb, 1.) In imagery of laminar flow of a fluid inside a circular pipe, thin cylindrical layers slide past each other, moving independently and with a varying range of speeds, hardly moving along the pipe surface and moving fastest in the central thread. In such imagery, the overall flow rate has a simple relationship to the pressure difference, namely, the Bernoulli equation that is based on conservation principles. (21.) Like the Ideal Gas Law that works for dilute gases, the Bernoulli equation is a successful model for actual flow of fluids in pipes limited to a certain class of situations that is based on low pressure.

When the pressure and flow rate become sufficiently large, laminar flow fails to model the phenomena, which turns into "turbulent flow." Turbulence is phenomena that is beyond the reach of physics to explain, describe or control in a satisfactory way. According to Feynman (*Lectures*, 3-9), "Nobody in physics has really been able to analyze it mathematically in spite of its importance to the sister sciences."

The first 561 pages of Lamb's classic *Hydrodynamics* are devoted to platonic constructions. Then, the author turns to " 'viscosity' or 'internal friction' which is exhibited more or less by all real fluids, but which we have hitherto neglected." A carefully constructed path of examples is set forth to "indicate the general character of the results to be expected in cases which are beyond our powers of calculation." (562.)

Only after such preparation does the author turn to the subject of "Turbulent Motion". "It remains to call attention to the chief outstanding difficulty of our subject. …the neglect of the terms of the second order seriously limits the application of many of the preceding results to fluids possessed of ordinary degrees of mobility. Unless the velocities, or the linear dimensions involved, be very small, the actual motion … is found to be very different from that represented by our formula. … [Reynolds investigated the] case of flow through a pipe … by means of filaments of colored fluid introduced into the stream. So long as the mean velocity (w_0) … falls below a certain limit … the flow is smooth … accidental disturbances are rapidly obliterated and the *régime* appears to be thoroughly stable. … As w_0 is gradually increased beyond this limit the flow becomes increasingly sensitive to small disturbances … When the rectilinear *régime* definitely breaks down the motion becomes wildly irregular, and the tube appears to be filled with interlacing and constantly varying streams, crossing and recrossing the pipe." (663-664.) .

Turbulent flow moves faster than is possible with laminar flow in the same-sized pipe but with increasing requirements in water pressure. It's like a price per pound of produce that stays the same unless you buy more than a certain limit, in which case the price per pound increases; and the more you buy over the limit the faster the price increases. That is, turbulent flow requires a wastage of energy in order to get a faster flow than is possible in the efficient laminar case. As in the example of audio circuits, the linear region is relatively simple but it is also limited to low volumes; and outside the limited linear region, things become much more complicated. The control variable (pressure) moves the system through the laminar range and the turbulent range.

The culminating class of control variable phenomena is metallurgical, specifically, the class of steel-making methods. I suggest that the control variable discussion of the two previous examples usefully applies to this more complex example. In all cases, an adjustable control variable is used to change smooth performance into rough performance that has a higher amount of activation. Here, the control variable is not a "quasi-static" variable like the volume control in audio circuits or the hydraulic pressure in water pipes. Rather, the control variable is a ***transformation speed***. To summarize chief facts: a slow transformation speed produces ***pearlite***; the transformation is continuous and described by quasi-static and linear processes. A fast transformation speed produces ***martensite***; the transformation is discontinuous and outside the reach of platonic science. Pearlite and martensite have distinctly different characters and properties, Metallurgists control pearlite transformations using simple principles but must grope experimentally when trying to control martensitic transformations.

I suggest that an obscured domain like that of martensitic transformations contains opportunities for development that are hidden in the complexities, like those that suggested a new metallurgical process to E. C. Bain in the 1930's, leading to development of "bainite." Metaphorically, in the terrain of metallurgy, pearlite occupies a site on a flat plain while martensite dwells in jagged mountain canyons.

Production of steel illustrates both successes of platonic principles and also their shortcomings.

A simple kind of steel is made of two components, 99% or so iron and 1% or so carbon. I focus here on a standard mix using 0.83% carbon. When the temperature of such steel is maintained above 1333 °F, a "red-hot" temperature, the crystals are called "face-centered" and the alloy is called ***austenite***. When the temperature is lower than 1333 °F, the crystals are called "body-centered" and the material can have different detailed forms and names depending on the "heat treatment" or production process. Pearlite is produced by a quasi-static process and is close to equilibrium; martensite is produced by a discontinuous process and is always far from equilibrium. After the process is complete, martensite has energy "frozen into" its structure but pearlite has effectively released any such "frozen" energy. Pearlite is softer and more workable while martensite is harder and more brittle. Pearlite is made up of microscopic layers of two different components that produce a shimmering appearance like that inside an oyster. Martensite is uniform and has a duller appearance.

The 1333 °F transition temperature resembles the freezing point of water. Above the transition temperature, iron crystals are face-centered. Below the transition temperature, iron crystals are body-centered. Differences between face-centered and body-centered forms are based on small differences between unit cells in the crystals. As iron cools, the crystals change form at the transition temperature like water freezes to ice. During the transition, iron nuclei shift in their positions relative to one another. In an isolated pure iron crystal, there is a collective shift of positions as the temperature passes through the transition. Such shifting is simple.

Pure iron behaves simply during passage through a transition from face-centered to body-centered crystals. Complexities and opportunities in steel-making come from the presence of carbon. Small amounts of carbon dissolve in austenite iron crystals where the form is face-centered. In other words, there is sufficient space inside face-centered iron crystals for carbon nuclei to move around.

In contrast to the relatively easy fit inside face-centered crystals, carbon nuclei do not fit easily inside body-centered crystals. If hot carbon steel is slowly cooled through the transition and iron nuclei shift from the face-centered form to the body-centered form, carbon nuclei inside the crystals distort the new body-centered crystals, leading to strain. Strain can be relieved by expelling carbon into spaces between crystals but it takes time for the carbon nuclei to move there. If the temperature is maintained at just below the transition temperature, nuclei move easily. Then, carbon is progressively expelled from the interiors of crystals and collects in the form of iron carbide (Fe_3C) particles in spaces between shrinking but purer iron crystals. Interstitial iron carbide particles grow and link up to form layers. The two-component structure of pearlite is formed in such a quasi-static formation process. Changes occur through the accumulation of small increments. Metallurgical investigations show that the process can be described by the diffusion equation, a linear form.

The formation process of martensite is very different. In contrast to the continuous process of pearlite, the formation of martensite is an example of a discontinuous transformation, like the radioactive transformations previously discussed. Perhaps a billet of red-hot steel is plunged into a vat of ice water. Sudden quenching causes the material to undergo fast powerful changes. Imagery suggests sharp discontinuities. The surface cools first and a "changing temperature front" moves inward, supposing that "changing temperature front" has a practical meaning. Apparently, "temperature change" moves through the material at close to the speed of sound, which is much faster in metals than in air. As "temperature change" passes through the material, carbon is trapped inside suddenly-formed body-centered crystals. Movements that would be easy if the metal were hot get "frozen" when the material suddenly becomes cold. Pervasive distortions and strains occur in tight but unorganized wrenching and pulling and squeezing that prevents some of the austenite from completing the transformation. Crystals are internally torn in a multitude of places, creating a network of "dislocations" that gives hardness to martensite. A high-energy sound wave may be emitted that resembles clicks or a scream. All details change abruptly, constrained only by collective bonds that hold the material together.

In sum, production of some kinds of steel, e.g., pearlite, is partially modeled by linear forms that describe fine movements and that provide continuous controls through "quasi-static" processes. Such linear forms and quasi-static processes fail to reach the more powerful activity that occurs during the making of martensite. Similar adaptations and failures appear in the transition from laminar flow to turbulence in water flow.

f. Laws of Physics fail to describe or control discontinuous transformations of water vapor into individual crystalline snowflakes.

Discontinuous transformations in steel-making show non-platonic aspects that become even more emphatic in processes that produce snowflakes from water vapor. Features of this beautiful phenomenon have parallels with freedom. It is wondrous how simple, common water goes through a transformational process that produces an enormous multitude of individual shapes; but, even under the most advantageous laboratory conditions, details are beyond understanding and transformations can only be partially controlled.

Physicists have investigated the formation of snowflakes for many years. Significant bodies of materials have been published by Ukichiro Nakaya (1900-1962), Kenneth G. Libbrecht and Yoshinori Furukawa. In a prior publication, "Facts about snowflakes," I used Libbrecht's online materials to show the failure of one branch of thermal physics (kinetic theory) to account for the production of snowflakes. (http://www.quadnets.com/testimony/snowflakes.html) Here. I make additional arguments about failures of statistical mechanics and classical thermodynamics.

Libbrecht's images, copied below from his website, show two stages of growth of a single ice crystal prepared in his laboratory, the smaller image after 5 minutes of growth and the larger after 10 minutes. The size of the larger crystal is 1.2 mm.

See http://www.its.caltech.edu/~atomic/snowcrystals/designer3/designer3.htm

The symmetries in these crystals raise the chief question. “The same” pattern appears in six different places that are separated by vast distances, if measured on an “atomic scale.” Given the enormous variety of snowflakes, it might seem that each branch of a single snowflake could, while growing, take on any one of a huge number of possible variations. Yet, all six follow almost exactly the same pattern. How can such a phenomenon occur?

> Libbrecht says (http://www.its.caltech.edu/~atomic/snowcrystals/faqs/faqs.htm):
>
> “What synchronizes the growth of the six arms? Nothing. The six arms of a snow crystal all grow independently, as described in the previous section. But since they grow under the same randomly changing conditions, all six end up with similar shapes.”
>
> “If you think this is hard to swallow, let me assure you that the vast majority of snow crystals are not very symmetrical. Don't be fooled by the pictures -- irregular crystals (see the Guide to Snowflakes) are by far the most common type. If you don't believe me, just take a look for yourself next time it snows. Near-perfect, symmetrical snow crystals are fun to look at, but they are not common.”

Libbrecht’s explanation or argument is not persuasive to me. The problem is not simply that “all six end up with similar shapes.” It is that there are apparently a great many possible shapes and all six end up with almost exactly the same shape. Shapes are being selected over vast distances.

Suppose that that each arm or branch of a snowflake can take on any of the possible shapes with equal and independent likelihood, a supposition based on the “fundamental hypothesis of equal *a priori* probabilities” of statistical mechanics. (Tolman 59, 350.) If there are 10 possible shapes, the probability of a snowflake having all branches with the same shape is 10^{-5}. (The choice for the first branch is arbitrary but then all other five branches must independently conform.)

Applying the binomial theorem and a probabilistic model, I estimate that the chance of producing a “hybrid snowflake” with three branches of one shape and three branches of another shape is much higher, about 100 times higher, than producing a snowflake with all six branches the same. It appears that, while incomplete or symmetry-less snowflakes are common, just as

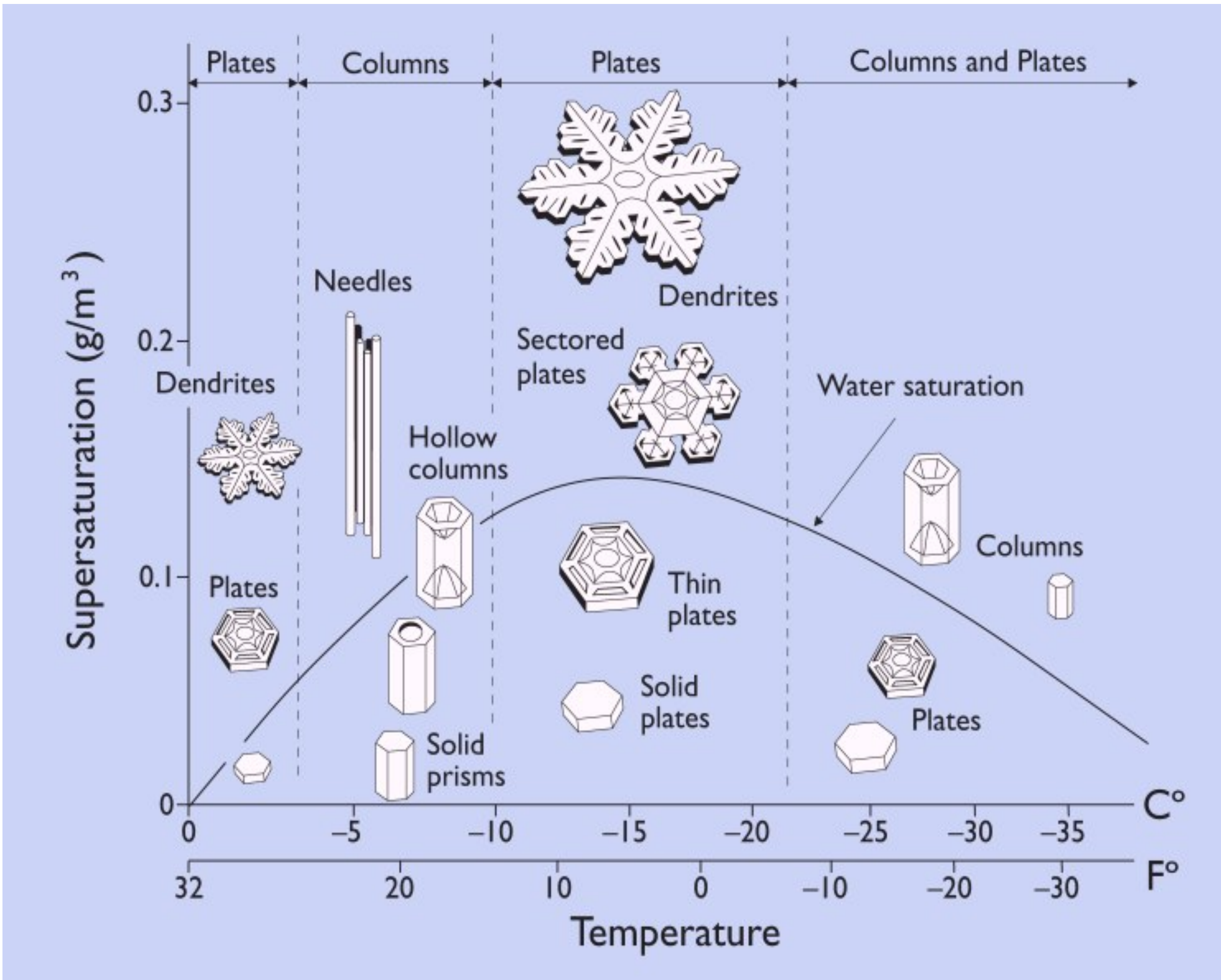
Libbrecht states, "hybrid snowflakes" with mixed symmetry are much rarer than those with six-fold symmetry. (See http://www.nasa.gov/pdf/183517main_snowcrystals.pdf and http://mynasa.nasa.gov/pdf/183516main_nakaya.pdf for snowflake variations.)

In other words, a "random" or "probabilistic" model does not account for near-perfect symmetry in different snowflake branches growing independently in a situation that is rich in possible alternatives. Libbrecht's answer "nothing" is nothing but faith in the power of platonic physics and the principle of sufficient reason, where symmetry is inherent in empty space and therefore, according to the faith, inherent in all things, even in the process of growing a snowflake.

I suggest, contrary to Libbrecht's assurances, that the production of snowflakes is an exemplar of phenomena that are outside the reach of platonic science. As a speculation for correction, I suggest an influence or "force" that stretches across the whole snowflake and that integrates the growth. Such a large-scale aggregational influence (called "non-local" in other different speculations) would be contrary to standard physics theories but seems to me to fit the phenomena.

Regardless of speculative corrections, I suggest that failures of Laws of Thermodynamics are shown by detailed snowflake phenomena organized in the "Nakaya diagram" shown on the next page, in a standard version copied from Libbrecht's website.

The Nakaya diagram is based on actual observations and shows how different environmental conditions produce different kinds of ice crystals and snowflakes. Crystals and flakes noted in the diagram were produced in Nakaya's laboratory and have been reproduced in other laboratories. Different conditions are described in terms of (1) temperature below freezing, or superfreezing, and (2) excess water in the air, or supersaturation.



Conditions for producing snowflakes can be compared with thermodynamic equilibrium, previously discussed. To get to equilibrium, the container is closed and isolated. Equilibrium vapor equals 100% humidity. Supersaturation is impossible in a system in equilibrium; excess water vapor results in condensation. Nor is superfreezing possible in equilibrium.

In a cloud, snow crystals grow from gaseous water vapor but no such growth can occur in an equilibrium system. In an equilibrium system at atmospheric pressure, water is liquid above 32 °F (0 °C) and solid below. Quasi-static processes in equilibrium systems are invariant. If the temperature goes down in tiny steps and rests between each step, water vapor condenses to liquid water and liquid water freezes to solid ice, like on a lake. In production of snowflakes, on the other hand, water vapor condenses directly on dust particles or other material points to form ice crystals. Libbrecht's lovely crystals are formed around the tips of electrified needles.

The Nakaya diagram has a place for equilibrium and quasi-static processes, namely, at the lower-left-hand corner of the diagram, where temperatures are just below freezing and supersaturation is close to 0. The Nakaya diagram indicates that, if the condition of air is displaced just a little bit from equilibrium, that is, if the air has just a little bit of excess water and is just a little bit below freezing, ice crystals will form that have shapes like small plates or prisms.

Moving away from the equilibrium point at the lower-left-hand corner of the Nakaya diagram, the situation becomes more problematical. Supersaturation and supercooling are not equilibrium conditions. Water vapor in such a condition is, in a certain sense, "waiting" for dust particles or other material points to condense onto; only at such material particles can equilibrium or some approximation thereto be attained. Water vapor "waiting" to condense is not at equilibrium and equilibrium principles do not necessarily apply during condensation processes.

According to the Nakaya diagram, snowflakes in six-branched symmetrical shapes called "dendrites" are produced in two distinct kinds of situations, both with considerable supersaturation, one with a small amount of superfreezing and the other, apparently more significant, with a large amount of superfreezing.

In other words, large amounts of supersaturation and superfreezing produce dendrite snowflakes that cannot be produced under equilibrium conditions or by means of quasi-static processes. The distinct, widely separated snowflake symmetries that are the focus of our inquiry come about by reason of discontinuous transformations. Vapor condenses directly onto a solid shape without the intervening step of liquid water. There is a complete change of form that occurs abruptly when compared to equilibrium processes. Although we can produce and observe such transformations, they are not within reach of our scientific models.

I suggest that supposed Laws of Thermodynamics fail to apply to the production of snowflakes. Indeed, said Laws fail to apply to most of the phenomena of actual life. As a particular example, Clausius' Second Law fails to apply to a situation with a maintained temperature gradient, such as a fire poker with one end in a steady flame and the other end in a bucket supplied with ice. Maintaining such a temperature gradient causes a continual, unbounded "increase in entropy" — but, of course, fuel and ice must be continually added. Clausius' Second Law applies only where entropy tends toward a maximum. ("Die Entropie der Welt strebt ein Maximum zu.") Please note that this is a system where "order" or "disorder" remain fixed. It is a steady-state system "far from equilibrium." (See Prigogine & Stengers.) The theory of thermal physics that successfully applies to this situation is Fourier's theory of heat conduction.

Truesdell (Tragicomedy, 34) commented on the limited nature of thermodynamics as constructed by Clausius: "The 'particular cases' into which CLAUSIUS chose not to enter included not only FOURIER's theory of heat conduction but also every non-trivial phenomenon described by mechanics or electromagnetic field theory. With this decree, thermodynamics turned its back on the real world. Henceforth, relinquishing steam engines, it would treat a 'universe' – an infinite space filled with some gas, the constitutive relation of which was specified only for the case when it was at rest with uniform density and temperature."

Later physicists attempted to extend principles that Clausius and other founders had propounded. The results fail to cohere. An earlier version of my views on philosophy of science, *A Patchwork Of Limits: Physics Viewed From an Indirect Approach*, quotes statements by thermodynamicists about their science:

"It is amazing to note the conflicting opinions expressed by eminent scientists." (I. Prigogine)

"We all seem to have a different, a private congenial way of justifying the First Law, etc., and argue about the rationale in each separate formalism." (J. Kestin)

"Thermodynamics is something which develops, which expands, which grows, and it has the capability of growing, and this kind of growing is just like the house that Jack built, by patching on and patching over and mending, and so this is the reason, I believe — the historical reason — why there are so many differences in deriving thermodynamic properties." (O. Redlich)

"The motivation for choosing a point of departure for a derivation is evidently subject to more ambiguity than the technicalities of the derivation. Motivation is tied up with psychological and philosophical factors, and these are nowadays not considered bona fide topics for public discussion." (L. Tisza)

"I hesitate to use the terms 'first law' and 'second law', because there are almost as many 'first laws' as there are thermodynamicists, and I have been told by these people for so many years that I disobey their laws that now I prefer to exult in my criminal status... The term 'entropy' seems superfluous, also, since it suggests nothing to ordinary persons and only intense headaches to those who have studied thermodynamics but have not given in and joined the professionals." (C. Truesdell)

"...[entropy] is a property, not of the physical system, but of the particular experiments you or I choose to perform on it." (E. T. Jaynes)

"...there cannot be a rigorous mathematical derivation of the macroscopic equations from the microscopic ones. Some additional information or assumption is indispensable. One cannot escape from this fact by any amount of mathematical funambulism." (N. G. van Kampen)

The following versions of the First and Second Laws of Thermodynamics are adapted from those stated at Morse, 94:

"$dU = dQ - p \times dV + \mu \times dn + J \times dL$

$dU \leq T \times dS - p \times dV + \mu \times dn + J \times dL$

where the equality holds for reversible processes,
the inequality for irreversible ones."

The first expression ($dU = dQ - p \times dV + \mu \times dn + J \times dL$) is a standard version of the First Law of Thermodynamics and states a principle of Conservation of Energy. Its meaning is similar to that of the Onsager Relations discussed above. It says that, if parts of a system at equilibrium are moved by tiny amounts and held at the new values, other parts of the system will adjust so as to return the system to equilibrium. Movable and adjustable parts are tracked by thermodynamic coordinates like p, V, T, n (standing for the number of molecules of a chemical species dissolved from a precipitate) and L (length). If, for example, there is a tiny change in volume, a dV, perfect equilibrium can be restored by means of tiny adjustments in a movement of heat (dQ), in the number of molecules (dn) and in the length of the body (dL) with respect to a stress (J). Tiny changes and adjustments can be accumulated through processes until they become substantial.

The First Law works where bodies belong to a class in which activity can be described and controlled by means of the "internal energy" of the system (U), a quantity invented by Clausius. The class is called "conservative bodies" and is similar to the class of "conservative systems" identified above by Gibbs. An Ideal Gas was the conservative body that Clausius used to develop and construct his system. An Ideal Gas is always in equilibrium and processes involving Ideal Gases are always reversible.

The First Law of Thermodynamics incorporates linear forms and describes behaviors of simple systems that have no memory and a range of equilibrium states. Linear concepts are further reflected in standard thermodynamics constructions based on Clausius' invention that use geometry and graphs, e.g., Legendre transformations and the lever rule for alloy compositions. The class of reversible processes is defined by "proportionals" p, μ (chemical potential) and J, which show continuing application of Pythagorean principles.

Rigorous applications of the First Law are limited to processes where an equilibrium point is moved quasi-statically. The First Law tracks changes taking place in a body when the body moves on a path made up of equilibrium points. This is a restricted class of bodies and processes.

A chief difficulty with trying to apply the Laws to snowflake production is the presence of many final equilibrium points that are distinctly different as to shape but that are indistinguishable in terms of system values such as temperature and vapor pressure. This factual phenomenon is contrary to the form of the First Law where each "point" – each set of system values – specifies a single equilibrium point. With snowflakes, such a "point" identifies a multitude of distinct snowflakes. Nor does there appear to be a useful relationship between the various snowflake shapes and an entropy function. The Laws of Thermodynamics do not provide assistance in tracing the production and development of individual snowflakes that have different shapes.

If the Second Law of Thermodynamics is to have the "equality" form mentioned in the Morse extract, there must be a set of reversible adjustments where $dQ = TdS$, with a well-defined "entropy function" S and "temperature" T. [In Clausius' construction, a well-defined entropy S is assumed to exist and temperature T then "pops out" of mathematics.] Adjustments are always in the form of relaxations. The Second Law prohibits the kind of excitatory activity that leads to relaxations but mandates relaxations that nullify such excitatory activity. The Second Law makes quietude the standard; only in quietude can entropy be exactly defined.

In actual life, however, many "irreversible" processes occur, such as those that produce snowflakes. Physicists' advanced constructions suggest an "excess increase in entropy," also called "entropy production," referring to an excess when compared to that resulting from reversible processes. Entropy production identifies a premium in energy expense that you have to pay to get the process done faster than the cheapest possible "reversible" process. It is like the additional added pressure needed to get turbulent water through a pipe faster than is possible with laminar flow. The technical term is ***dissipation***. I suggest that similar premium or additional dissipations of energy leads to the individual character of snowflakes. Advanced constructions suggest that some "dissipated heat" or "produced entropy" goes into such character. (Prigogine & Stengers, 267-290.) In sum, it appears that dissipation and irreversible processes are active in the production of individual snowflakes and provide a partial account for their character. Conservation is equivalent to invariance; dissipation is needed for individuals.

To qualify as a reversible process, "two conditions must be satisfied — namely, (1) the process must be quasi-static; (2) there must be no dissipative processes, such as frictional effects or elastic hysteresis." (Sprackling, 37.) "During a reversible process, a system must always be infinitesimally close to equilibrium and, in particular, to thermal equilibrium." (*Id*., 38.)

"Finite, reversible processes cannot occur in practice, as no process is entirely free from frictional or other dissipative effects nor, frequently, can the process be carried out so slowly that at all stages the system is able to adjust to the changing conditions and remain infinitesimally close to a state of thermodynamic equilibrium. The reversible process is, therefore, an ideal limit at which dissipation and non-equilibrium vanish; it is the limit of what is possible in practice. Its importance is that it is the only type of process for which exact calculations can be performed in terms of the simple description of a system and its interactions, using thermodynamic coordinates." (*Id*., 39.)

In sum, "entropy" is well-defined only for reversible processes. More precisely, only cyclical reversible processes conserve entropy. Entropy-conserving processes are like linear amplifiers and laminar flow at low pressure in pipes. Non-linearity and turbulence degrade the concept of entropy like noise degrades the message in a signal. It appears that individualized action requires violation of such defining constraints and is achieved through such disruptive means.

The Laws of Thermodynamics would prohibit the individualized character of snowflakes. Unlike an equilibrium system where the final state is determined, there are a multitude of possible final snowflake states and no way to distinguish them. There is no quasi-static path that connects supersaturated water vapor to superfrozen ice crystals. Yet growth of an individual snowflake appears to be organized by a principle that reaches across the whole thing. Platonic science cannot handle such facts. The only explanation of platonic science for the astonishing and beautiful varieties of snowflakes is that stated by Libbrecht: "nothing."

5. Modern cognitive psychology and brain science derogate muscular movements and related bodily feelings of actual life; instead, depersonalized information is supposed to be processed according to forms of computation based on principles of platonic science.

    a. The alternative approach provides a view of brain operations in which muscular movements have foundational importance.

The alternative approach stands independently of scientific approaches and, indeed, as a rival to scientific approaches. Although they are independent, the two approaches have much in common. Both construct idealized forms in imaginary domains; and timing device designs resemble electronics designs. In other ways, the approaches are very different.

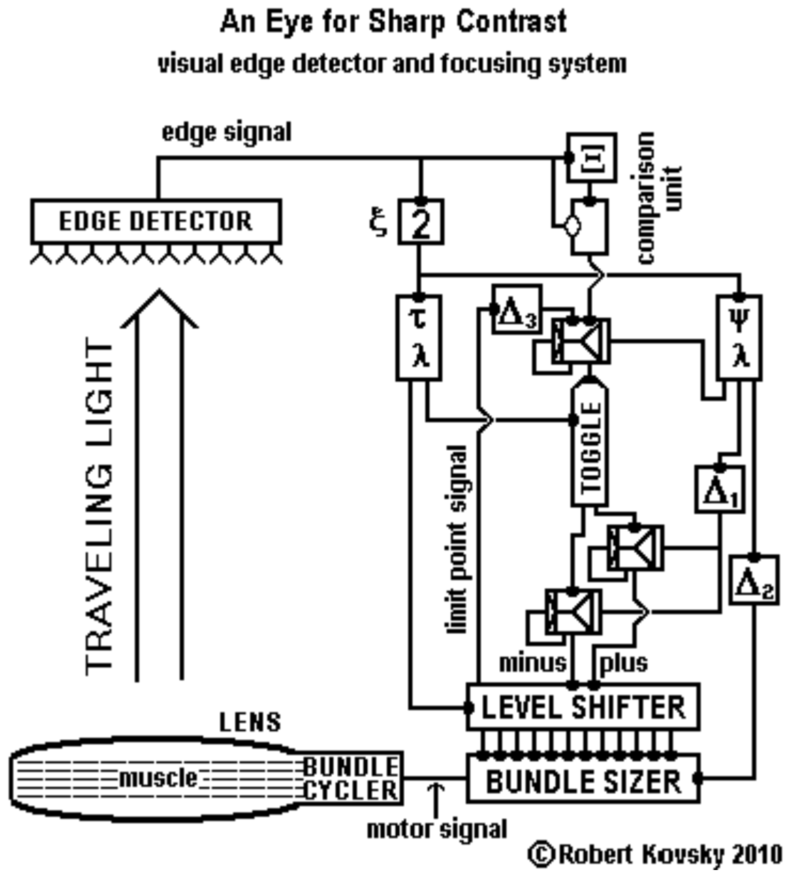
One large-scale difference is that scientific constructions are built from ***states*** while alternative constructions are built from units of ***action***, e.g., "action pulses" in timing devices. Details are discussed in the online presentation of "An Eye for Sharp Contrast." From an action perspective, I suggest that scientific psychologies erroneously neglect an organism's muscular movements and related bodily feelings and, instead, focus on image processing based on sensations.

While muscular movements are primal in the alternative approach, images have important functions. Some images — e.g., sights and sounds — are used by an organism to control muscular movements. Images may take center stage during dramatic and memorable moments. However, mental images detached from action, such as numbers, seem to be limited to human beings. In my approach, image processing is deferred and initial models are developed without imagery; then imagery can be added when required for a task, perhaps as a trigger for an "action fiat," e.g., noticing that the traffic light has changed from red to green as a trigger to start moving.

"Action fiat" is a term used by William James in *The Principles of Psychology* (1890), accessible at http://psychclassics.yorku.ca/James/Principles/index.htm. James' treatise is enormously rich in observation, invention, scholarship and error — and its influence continues here. In contrast to builders of current brain models, James focused on "feelings." He adapted a prior magazine article titled "The Feeling of Effort" in his chapter on "Will." James expressly considered and rejected primary roles for bodily feelings based on muscular movements. In his treatment, such bodily feelings are assimilated to sensory processing and mental relations. A central processor receives inputs from sensory organs and produces outputs to muscles and glands. By means of "ideo-motor action" of the brain, sensory images cause muscular movements. Sometimes, an "action fiat" pulls the trigger. "Free will" can decide events but only in "an operation amongst … physiological infinitesimals."

Modern research has disproved key factual assertions in James' model. Muscular movements clearly do generate bodily feelings; and bodily feelings clearly do influence muscular movements in direct and ongoing ways. Unfortunately, derogation of muscular movements and related bodily feelings continues implicitly in theories of cognitive psychology and related brain models. Such derogation contributes to depersonalization that is suited to principles of computation.

In contrast to scientific models, the technical design of "An Eye for Sharp Contrast" shown on the next page illustrates the primacy of muscle-like movements in my constructions. The "edge signal" is prior to imagery but an imaging module could be attached to it. The design of "A Dogtail for Wagging" below similarly illustrates primacy of movement. Systems that perform such muscle-like movements lead to forms of episodic balancing and suggested applications to actual life. Focusing on an edge as performed by the Eye is a rudimentary kind of balancing.



In the Eye, a muscle girdles and squeezes the Lens, controlling its focal length and modifying optical images it projects. Squeezing is maintained by pulse bundles held in Bundle Cycler. Squeezing changes when a new bundle appears on the motor signal line from Bundle Sizer, with a strength Level that shifts according to settings of Level Shifter. When the Eye is operating, there is a new motor signal and a shift in such Level during each operating cycle, which occurs with period ψ. Bundle Cycler, Bundle Sizer and Level Shifter are "movement generator parts" that cause and control muscular movements whenever the Eye is operating.

Operations of such movement generator parts are subject to "controller parts," here Toggle and comparison unit. "Sensory parts" produce signals that influence controller parts; here, Edge Detector generates the edge signal that goes into the comparison unit. Edge signals are based on optical images of environmental objects that are projected by light traveling through the Lens onto devices in Edge Detector that mimic retinal cells. A high-frequency edge signal identifies a sharp edge in such an optical image; a low-frequency signal identifies a diffuse edge.

During operations, the Eye sharpens the edge in such an image by stepped adjustments in the strength of the muscle that is squeezing the Lens. Operating as designed, the Eye focuses on the edge of an object and "follows" a slowly moving object.

Suppose that the Eye is operating in the absence of an object: the muscle steps through its entire range, going from the strongest to the least squeezing, back and forth – until an object with an edge enters the visual field and an edge signal appears. Then the Eye focuses on the edge.

In my models, muscle-like devices are always activated. I suggest that voluntary muscles in legs and arms run "on their own" by means of "bundle cyclers" in spinal vertebra and that muscles and related feelings operate even in the absence of a central brain, as illustrated by vivisection of the "spinal frog" in Chapter 2 of James' treatise, by the chicken flopping around with its head cut off on YouTube and by the "brainless cat [that] can still walk on a treadmill." (Calvin discussing a "pattern of action" that "can be spinal cord alone, or brain commanding spinal cord." P. 214.)

In the Eye for Sharp Contrast, movement generator parts run "on their own," producing motor signals prior to control by sensory signals. Any control must match the repertoire of motor signals. In this design, the repertoire is very small and the control is very simple.

One important feature of the Eye is that there is a simple relationship between the size of pulse bundles in Bundle Cycler and the distance to an object seen by the Eye. Each strength of squeezing of the Lens corresponds to a distinct region in environmental space where objects are in focus. It might be possible to calculate the distance from the Eye to an object from the size of pulse bundles that keep the object in focus. A "look-up" table could list pulse bundle sizes and the corresponding distances of an object kept in focus. On the other hand, the value of the edge signal reveals nothing about the distance to the object. The edge signal shows whether the edge of an image is sharp or diffuse; this occurs much the same at any distance.

I suggest that similar reasoning applies to any animal eye where the focal length of a lens is controlled by muscles. There is a useful relationship between motor signals to such muscles and the distance to an object being held in focus. The relationship can provide the animal with a basis for action, e.g., in deciding whether or not to flee. Of course, distance detection is improved with two eyes that can be used for "range-finding" (two eyes move inward as an object approaches directly) and/or for complex image processing that underlies depth perception. A person can see the improvement by looking first with one eye and then with two eyes. But the experiment also shows that useful distance detection occurs with a single eye that shifts from near to far focus and back again. Nearer and farther can be felt in the eye muscle. Calculating distance from values of a motor signal to a muscle would appear to be faster and more direct than calculating distances by coordinating movements or by imaging depths. I suggest that range-finding and/or depth imaging in visual perception of distance may be secondary processes and that a primary process may be based on motor signals that drive focusing muscles of a lens.

Further development of the argument suggests that visual perception of a scene involves motor signals that cause the gaze to jump in saccadic movements of the eye, as well as by processing of retinal patterns. I suggest that a spatial description of a scene can be built piecewise from eye jumps that shift from object to object, guided by edges — as well as from a global mental map into which objects are inserted. I suggest that timing devices can mimic the vestibulo-optical reflex or VOR, which generates saccadic eye movements that automatically keep a jogger's gaze fixed on a goal. For many tasks of actual life, such as dodging fixed objects and other pedestrians while walking on a crowded sidewalk or "slamming on the brakes" while driving a car, as discussed in the opening pages of the essay, saccadic muscular movements of the eyes might speedily provide all the "spatial representation" that is needed. I suggest that, while a person is walking on the sidewalk, muscular movements of the eyes can control muscular movements of the pelvis without the use of images. I suggest that specific pattern recognition, e.g., recognizing a face among passersby, is a different kind of function but one that depends on a foundation of muscular movements. I suggest that saccadic movements of the eyes provide actual foundations for imagery of the focused gaze.

b. Although William James recognized issues of muscular movements and related bodily feelings, he made bodily feelings into sensory inputs to a centralized system which generates muscular movements as outputs.

Modern brain science originates with James' treatise, *The Principles of Psychology* (1890). Ideas that James introduced or held, such as darwinism, are still influential. In contrast to some modern scientists, however, James was opposed to the elevation of human concepts into authoritarian cosmological principles, what I call platonism; and he developed his opposition into the philosophy of Pragmatism. In § 6.f, I discuss the pragmatic jurisprudence of Oliver Wendell Holmes, Jr., a friend of James who shared many of his views. (Menand.)

James tried to construct a psychology that connected a lifetime of introspective personal observations with laboratory vivisection of frogs (Chap. 2). Primary construction materials were called "feelings." James understood that platonizing scientists often denied that feelings have a place in "reality." In a related article, "Are We Automata," he wrote:

"The desire on the part of men educated in laboratories not to have their physical reasonings mixed up with such incommensurable factors as feelings is certainly very strong. Nothing is commoner than to hear them speak of conscious events as something so essentially vague and shadowy as even doubtfully to exist at all. I have heard a most intelligent biologist say: 'It is high time for scientific men to protest against the recognition of any such thing as consciousness in a scientific investigation'. In a word, feeling constitutes the 'unscientific' half of existence, and any one who enjoys calling himself a 'scientist' will be too happy to purchase an untrammeled homogeneity of terms in the studies of his predilection …"

In the "Automata" article, James concluded that "the mind is at every stage a theatre of simultaneous possibilities" and that on "our mental stage Feeling always selects." He rejected the "automaton theory" of Thomas Huxley "which denies causality to feeling." "And I moreover feel that that unstable equilibrium of the cerebrum which forms the pivot of the argument just finished may, with better knowledge, be found perfectly compatible with an average appropriateness of its actions taken in the long run." [As discussed below, proposed Shimmering Sensitivity embodies an "unstable equilibrium of the cerebrum" whereby Feelings can select. "Unstable equilibrium" also appears in contests that are controlled by episodic balancing forms.]

According to James, feelings arise in the "wonderful stream of our consciousness" discussed in The Stream of Thought. (Chap. 9.) James notes differences between slow and rapid movements of the stream and between stable and flighty images within it. "[W]hat strikes us first is this different pace of its parts. Like a bird's life, it seems to be made of an alternation of flights and perchings. … *Let us call the resting-places the 'substantive parts,' and the places of flight the 'transitive parts,' of the stream of thought.*" According to James, the transitive parts resist analysis or even scrutiny. "The attempt at introspective analysis in these cases is in fact like seizing a spinning top to catch its motion, or trying to turn up the gas quickly enough to see how the darkness looks." Addressing such problems, one group of thinkers, the Sensationalists, "denied that feelings of relation exist" and another group, the Intellectualists, adversaries of the Sensationalists, "made the same admission that the feelings do not exist. … But from our point of view, both Intellectualists and Sensationalists are wrong. If there be such things as feelings at all, *then so surely as relations between objects exist in rerum naturâ, so surely, and more surely, do feelings exist to which these relations are known*. … We ought to say a feeling of *and*, a feeling of *if*, a feeling of *by*, quite as readily as we say a feeling of *blue* or a feeling of *cold*."

James started with a broad concept of "feeling." In my constructions, I use the word "imagery" as a general term and the word "feelings" is used for particular kinds of imagery, first for images based on bodily activity and then for imagery of music, emotions and moods. "Awareness" of feelings is additional imagery that overlays feelings. Feelings that have become subjects of awareness can sometimes be made into mental images, e.g., temperatures. However, many mental images such as "if" are not based on feelings, as I use that term, but on mental operations.

James shifts his emphasis to feelings that refer to mental relations. According to James, "*there is no proof that the same bodily sensation is ever got by us twice.*" (Chap. 9.) Those who follow such a view typically exclude bodily feelings based on muscular movements from mental structures that have defined classes. I do not concur in James' view since harmonic feelings in music, bodily feelings in yoga practice and other feelings associated with bodily sensations can be duplicated very closely by means of training. In other words, training develops repetitive forms of music and body consciousness, each with its own specialized kinds of feelings.

James discusses muscular movements in culminating chapters of his treatise. In "The Production of Movement" (Chap. 23), James asserts that the "whole neural mechanism is … but a machine for converting stimuli into reactions." The "intellectual part of our life is … the middle or 'central' portion of the machine's operations" that produce "the final or emergent operations, the bodily activities." James previews and surveys the "detailed study of the more important classes of movement consequent upon cerebro-mental change: They may be enumerated as — 1) Instinctive or Impulsive Performance; 2) Expressions of Emotion; and 3) Voluntary Deeds." "Using sweeping terms and ignoring exceptions, *we might say that every possible feeling produces a movement, and that the movement is a movement of the entire organism, and of each and all of its parts*."

James' model is a machine that produces movements from feelings. In other words, he asserts that images cause muscular movements. He reiterates his mechanistic principles from multiple perspectives. They culminates in ideo-motor action and deliberative action discussed below. The initial summary (Chap. 2) declares: "The afferent nerves, when excited by some physical irritant, … conveys the excitement to the nervous centres. The commotion set up in the centres does not stop there but discharges itself … through the efferent nerves into muscles and glands…"

An extreme example is the statement in Chapter 4 on Habit:

"The only impressions that can be made upon [brains] are through the blood, on the one hand, and through the sensory nerve-roots, on the other; and it is to the infinitely attenuated currents that pour in through these latter channels that the hemispherical cortex shows itself to be so peculiarly susceptible. ***The currents, once in, must find a way out***." (Emphasis added.)

Thus, James recognizes muscular movements as results that appear only after a focal commotion in the central centres is resolved and discharged through efferent currents. Movements affect brains only indirectly, "through the sensory nerve-roots." It is an "input-output" model with "feedback" from output to input. It neglects, however, organisms that move on their own, as well as creative skills, such as those of musicians, that are developed through training.

Chapter 26 on Will begins with "Desire, wish, will…" and declares that "The only ends which follow *immediately* upon our willing seem to be movements of our own bodies." A note refers to a previously-published article titled *The Feeling of Effort*. In the article, James wrote:

“In opposition to this popular view [advocated by other scientists], I maintain that the feeling of muscular energy put forth is a complex afferent sensation coming from the tense muscles, the strained ligaments, squeezed joints, fixed chest, closed glottis, contracted brow, clenched jaws, etc., etc. That there is over and above this another feeling of effort involved, I do not deny; but this latter is purely moral and has nothing to do with the motor discharge. We shall study it at the end of this essay, and shall find it to be essentially identical with the effort to remember, with the effort to make a decision, or to attend to a disagreeable task.”

It appears that James viewed feelings from muscular movements much as sensory inputs that are like mental relations. Such feelings influence further movements through cerebral processing. In alternating steps, feelings cause movements and movements cause feelings. The “feelings cause movements” step can be mediated by conscious decisions but the “movements cause feelings” step occurs through sensory processes and have no other route to consciousness. On the last point, James was adamant. “ ‘A motion becomes a feeling!’ —no phrase that our lips can frame is so devoid of apprehensible meaning. … (Quoting Spencer) a unit of feeling has nothing in common with a unit of motion.” (Chap. 6.) James repeatedly stood opposed to “the advocate of perception by muscular feelings.” “*It seems to me that no evidence of the muscular measurements in question exists*; but that all the facts may be explained by surface-sensibility, provided we take that of the joint-surfaces also into account.” (Chap. 20, Perception of Space.) The chief mention of muscular matters in Chap. 17 on Sensation refers to what we call “phantom limbs” felt by an amputee or paralyzed person. “We shall learn in the chapter on Space that our feelings of our own movement are principally due to the sensibility of our rotating *joints*.”

In Chapter 21, The Perception of Reality, James remarks on “the prerogative position of sensations in our belief.” After constructing his theory of reality around sensations, James considers “our treatment of tactile and muscular sensations as ‘primary’ qualities more real than those ‘secondary’ qualities which eye and ear and nose reveal.” He declares that tangible objects are important as instruments of pain or pleasure and that eye and ear “are but organs of anticipatory touch.” He states that “[W]e can only use an object for our advantage when we have it in our muscular control,” Then he passes on to emotion, which “has as much to with our belief in an object’s reality as the quality of giving pleasure or pain.” Notwithstanding such gestures towards actual life, for James, issues of reality and belief are mostly concerned with visible objects. In this view, reality comes to us through our senses.

In Chapter 26 on Will, James derogates feelings that are based on muscular movements by means of classes of ***resident*** and ***remote***. He concludes that feelings that reside in moving body parts are less important than brainy feelings remote therefrom. James states that: “*all our ideas of movement*, including those of effort which it requires, as well as those of its direction, its extent, its strength, and its velocity, *are images of peripheral sensations, either* '*remote*,' *or resident in the moving parts, or in other parts which sympathetically act with them in consequence of the* '*diffusive wave*.'

“If the ideas by which we discriminate between one movement and another, at the instant of deciding in our mind which one we shall perform, are always of sensorial origin, then the question arises, ‘Of which sensorial order need they be?’ It will be remembered that we distinguished two orders of kinæsthetic impression, the *remote* ones, made by the movement on the eye or ear or distant skin, etc., and the *resident* ones, made on the moving parts themselves, muscles, joints, etc. Now do resident images, exclusively, form what I have called the mental cue, or will remote ones equally suffice?

"*There can be no doubt whatever that the mental cue may be either an image of the resident or of the remote kind*. Although, at the outset of our learning a movement, it would seem that the resident feelings must come strongly before consciousness, later this need not be the case. The rule, in fact, would seem to be that they tend to lapse more and more from consciousness, and that the more practised we become in a movement, the more 'remote' do the ideas become which form its mental cue. What we are *interested* in is what sticks in our consciousness; everything else we get rid of as quickly as we can. Our resident feelings of movement have no substantive interest for us at all, as a rule. What interest us are the ends which the movement is to attain. Such an end is generally an outer impression on the eye or ear, or sometimes on the skin, nose, or palate. Now let the idea of the end associate itself definitely with the right motor innervation, and the thought of the innervation's *resident* effects will become as great an encumbrance as we formerly concluded that the feeling of the innervation itself would be. The mind does not need it; the end alone is enough.

"The idea of the end, then, tends more and more to make itself all-sufficient. …

"The reader will certainly recognize this to be true in all fluent and unhesitating voluntary acts. The only special fiat there is at the outset of the performance." (p. 519, last sentence *sic*.)

Thus, James derogates "resident images" or "resident feelings of movement," what I call "body images" or "bodily feelings." James' solution to the puzzle of how to attribute causal power to imagery is carried forward in an extended construction that disregards muscular movements, and leads to a mechanistic theory stated on p. 497 of Dover's printed version of the treatise, a number later used as a reference. On p. 497, the theory is stated in a suppositional or hypothetical way. In the later reference, it is treated as factual.

On pages 497-498, James states (***bold-italics*** emphasis added, footnote omitted):

"Now if we analyze the nervous mechanism of voluntary action, we shall see that by virtue of this principle of parsimony in consciousness the motor discharge *ought* to be devoid of sentience. If we call this immediate psychic antecedent of a movement the latter's *mental cue*, all that is needed for invariability of sequence on the movement's part is a *fixed connection* between each several mental cue, and one particular movement. For a movement to be produced with perfect precision, it suffices that it obey instantly its own mental cue and nothing else, and that this mental cue be incapable of awakening any other movement. Now the *simplest* possible arrangement for producing voluntary movements would be that the memory-images of the movement's distinctive peripheral effects, whether resident or remote, themselves should severally constitute the mental cues, and that no other psychic facts should intervene or be mixed up with them. ***For a million different voluntary movements, we should then need a million distinct processes in the brain-cortex (each corresponding to the idea or memory-image of one movement), and a million distinct paths of discharge. Everything would then be unambiguously determined, and if the idea were right, the movement would be right too. Everything after the idea might then be quite insentient, and the motor discharge itself could be unconsciously performed.***"

The foregoing passages are preparation for the construction that was James' chief goal and that expresses the central element of a "free will" analysis, by means of which "images cause movements" (**bold** emphasis added):

"**Ideo-Motor Action.**

"The question is this: *Is the bare idea of a movement's sensible effects its sufficient mental cue* (p. 497), *or must there be an additional mental antecedent, in the shape of a fiat, decision, consent, volitional mandate, or other synonymous phenomenon of consciousness, before the movement can follow*?

"I answer: Sometimes the bare idea is sufficient, but sometimes an additional conscious element, in the shape of a fiat, mandate, or express consent, has to intervene and precede the movement. The cases without a fiat constitute the more fundamental, because the more simple, variety. The others involve a special complication, which must be fully discussed at the proper time. For the present let us turn to ***ideo-motor action*****, as it has been termed, or the sequence of movement upon the mere thought of it, as the type of the process of volition**.

"Whenever movement follows *unhesitatingly and immediately* the notion of it in the mind, we have ideo-motor action. We are then aware of nothing between the conception and the execution. All sorts of neuro-muscular processes come between, of course, but we know absolutely nothing of them. We think the act, and it is done; and that is all that introspection tells us of the matter. … I sit at table after dinner and find myself from time to time taking nuts or raisins out of the dish and eating them. My dinner properly is over, and in the heat of the conversation I am hardly aware of what I do, but the perception of the fruit and the fleeting notion that I may eat it seem fatally to bring the act about." (Pages 522-523.)

Ideo-motor action provides grounds for James' further constructions set forth below. In sum, "currents" often "run in at one nerve" and then "they run out again at another" to instigate movements. However, currents can be blocked by "antagonists." James posits a "fiat" that lifts the block and that is based on "representations." Hence, representations cause movements.

"We may then lay it down for certain that *every representation of a movement awakens in some degree the actual movement which is the object; and awakens it in a maximum degree whenever it is not kept from so doing by an antagonistic representation present simultaneously to the mind*.

"The express fiat, or act of mental consent to the movement, comes in when the neutralization of the antagonistic and inhibitory idea is required. But that there is no express fiat needed when the conditions are simple, the reader ought now to be convinced. … Every pulse of feeling which we have is the correlate of some neural activity that is already on its way to instigate a movement. Our sensations and thoughts are but cross-sections, as it were, of currents whose essential consequence is motion, and which no sooner run in at one nerve than they run out again at another. … But where there is no blocking, there is naturally no hiatus between the thought-process and the motor discharge. *Movement is the natural immediate effect of feeling, irrespective of what the quality of the feeling may be. It is so in reflex action, it is so in emotional expression, it is so in the voluntary life*. Ideo-motor action is thus no paradox, to be softened or explained away. It obeys the type of all conscious action, and from it one must start to explain action in which a special fiat is involved."

The "antagonistic representation" becomes a central player in ACTION AFTER DELIBERATION. James interprets the "Stream of Thought" to mean "a mind with one idea before it, of many objects, purposes, reasons, motives related to each other, some in a harmonious and some in an antagonistic way." That is, "however complex the object may be, the thought of it is one undivided state of consciousness." James considers the notion that "the elements of the subjective stream are discrete and separate and constitute what Kant calls a 'manifold.' " James requires that "the manifold of ideas has to be reduced to unity." As he earlier stated: There is a "Unity of one Thought." Accordingly: "*There is no manifold of coexisting ideas*; the notion of such a thing is a chimera. *Whatever things are thought in relation are thought from the outset in a unity, in a single pulse of subjectivity, a single psychosis, feeling, or state of mind.*" James cites Brentano: "Altogether this chapter of Brentano's on the Unity of Consciousness is as good as anything with which I am acquainted."

Having established the necessary Unity behind antagonists, James proceeds to his conclusion.

"We are now in a position to describe *what happens in deliberate action*, or when the mind is the seat of many ideas related to each other in antagonistic or in favorable ways. One of the ideas is that of an act. By itself this idea would prompt a movement; some of the additional considerations, however, which are present to consciousness block the motor discharge, whilst others, on the contrary, solicit it to take place. The result is that peculiar feeling of inward unrest known as *indecision*. Fortunately it is too familiar to need description, for to describe it would be impossible. As long as it lasts, with the various objects before the attention, we are said to *deliberate*; and when finally the original suggestion either prevails and makes the movement take place, or gets definitively quenched by its antagonists, we are said to *decide*, or to *utter our voluntary fiat* in favor of one or the other course. The reinforcing and inhibiting ideas meanwhile are termed the *reasons* or *motives* by which the decision is brought about.

"The process of deliberation contains endless degrees of complication. At every moment of it our consciousness is of an extremely complex object, namely the existence of the whole set of motives and their conflict… The deliberation may last for weeks or months, occupying at intervals the mind. The motives which yesterday seemed full of urgency and blood and life to-day feel strangely weak and pale and dead. But as little to-day as to-morrow is the question finally resolved. Something tells us that all this is provisional; that the weakened reasons will wax strong again, and the stronger weaken; that equilibrium is unreached; that testing our reasons, not obeying them, is still the order of the day, and that we must wait awhile, patient or impatiently, until our mind is made up 'for good and all.' This inclining first to one then to another future, both of which we represent as possible, resembles the oscillations to and fro of a material body within the limits of its elasticity."

James also addressed **THE QUESTION OF 'FREE-WILL.'** "My own belief is that the question of free-will is insoluble on strictly psychologic grounds." Free-will ends up not being important to James: "the operation of free effort, if it existed, could only be to hold some one ideal object, or part of an object, a little longer or a little more intensely before the mind. Amongst the alternatives which present themselves as *genuine possibles*, it would thus make one effective. And although such quickening of one idea might be *morally and historically momentous*, yet, if considered *dynamically*, it would be an operation amongst those physiological infinitesimals which calculation must forever neglect."

Comparison of my approach with that of James discloses similarities and differences. As for similarities, James' "currents" are activated elements of construction; and James conceives of brains as operating for purposes of action. There is a pivotal "unstable equilibrium of the cerebrum." James recognizes "alternatives which present themselves as *genuine possibles*" and he acknowledges the selective power of feelings. He declares: "Every pulse of feeling which we have is the correlate of some neural activity that is already on its way to instigate a movement."

He illuminates targets for constructions, e.g., in Chapter X, The Consciousness of Self: A "bald fact is that *when the brain acts, a thought occurs*. The spiritualistic formulation says the brain–processes knock the thought, so to speak, out of a Soul which stands there to receive their influence. … And what is the 'knocking' but the *determining of the possibility to actuality*?"

Differences between James' approach and mine are rooted in metaphysics. Although he entertained doubts, James adhered to the metaphysics that declares "I think, therefore I am." (Chap. VIII.) My metaphysics is grounded in muscular movements: "I move, therefore I am. I move whether or not I'm thinking about it." (See *id*., "Locke … attacks the Cartesian belief…: 'Every drowsy nod shakes their doctrine who teach that their soul is always thinking.' ")

From a critical perspective, James was committed to a centralized input-output model of brains and psychology that has hegemonic power and that conforms at least 99% to mechanistic principles. Although James was an exemplar of open-mindedness, he closed his mind repeatedly to facts of actual life. His introspective investigations failed to recognize obvious features of common experience. Apparently, his bodily condition was sedentary and his mental condition was detached from matters under consideration.

Thus, James showed his limitations when he declared that "The only impressions that can be made … are through the blood … and through the sensory nerve-roots," when he opposed "perception by muscular feelings," when he assumed that "the ideas by which we discriminate between one movement and another, at the instant of deciding in our mind which one we shall perform, are always of sensorial origin" and when he asserted that "*there is no proof that the same bodily sensation is ever got by us twice.*"

James recognized two distinct sources of feelings, "resident" and "remote." Only "remote" feelings suited his input-output machine model and he constructed arguments to justify disregard of "resident feelings." "What we are *interested* in is what sticks in our consciousness; everything else we get rid of as quickly as we can. Our resident feelings of movement have no substantive interest for us at all, as a rule." He used the word "feelings" in a shifty fashion, trying to cloth airy abstract relations with the earthiness of actual life while at the same time denying influential power to that life. James argued, much like Nietzsche and Plato, that models of brains and psychology made in images of their cerebral creators are binding on all persons in all situations.

James limits his model to a deliberation process that "contains endless degrees of complication." Choice is restricted to mental activity that must be completed before action can be commenced. "Now" choices that are made in sports competitions and musical performances are ignored.

Most glaring of James' errors is the pivotal assertion on pp. 497-498: "For a million different voluntary movements, we should then need a million distinct processes in the brain-cortex (each corresponding to the idea or memory-image of one movement), and a million distinct paths of discharge. Everything would then be unambiguously determined…" The word "million" denotes a huge number. But the number of possible voluntary movements in daily life, sports, music and building projects like houses and electronics is way beyond a simple "million." James requires distinguishable voluntary movements so that determinate connections can be made between images and such movements. Simply to state the task in James' terms shows that his approach cannot succeed. Like other scientific psychologists, James fails to account for or incorporate crucial connections between images and movements.

c. Even more than James, modern cognitive psychology views human beings as depersonalized processors of information, with action as an abstract final result.

James was a pioneer, working as an original creator in novel areas of investigation and having to contend with historical burdens that stretched back to ancient philosophers. He exemplifies the maxim of Goethe noted above that "A false hypothesis is better than none." Nietzsche declared: "The errors of great men are venerable because they are more fruitful than the truths of little men." James' treatise and brain models, despite their errors, were enormously fruitful. Modern brain models and cognitive psychology have their origins in William James.

It is useful to compare James' model with modern scientific models. In *A Cognitive Theory of Consciousness*, Bernard Baars follows James in important respects, especially as to "Will" or "Volition," where Baars updates James' "ideomotor theory." Topics of ***computers*** are investigated by William H. Calvin in *The Cerebral Symphony: Seashore Reflections on the Structure of Consciousness*, which is especially concerned with muscular movements, and by Christof Koch in *Biophysics of Computation: Information Processing in Single Neurons* (1999), which constructs a version of the "standard physical model" of neuronal operations that is aimed at computation. Koch's later book, *The Quest for Consciousness: A Neurobiological Approach*, is also discussed. My review is highly selective for purposes of critical analysis. All the authors have contributed to my development.

Historical background is provided by Baars, *The Cognitive Revolution in Psychology* (1986):

"For at least 50 years, until very recently, scientific psychology was dominated by a philosophy of science known as behaviorism. Behaviorism is, in many ways, a radical position. Many behaviorists denied the legitimacy of ideas such as consciousness, thinking, feeling, motives, plans, purposes, images, knowledge, or the self. Much of the everyday vocabulary we take for granted in describing human behavior and experience was rejected as unscientific." (p. 1.)

"Behaviorism as an intellectual discipline forces psychologists to *distance* themselves from the everyday psychology that we all live." (43.)

According to Baars (81), at a "rather small conference" at Massachusetts Institute of Technology in 1956, "practically all the people who were to play a major role in the cognitive revolution" discussed "all the major themes of the cognitive revolution that was just about to begin" and replace behaviorism. Such major themes of the cognitive revolution are listed as topics: "The Computational Metaphor and the Role of Experiments … The Computational Rationale for the Cognitive Revolution … Information, Automata, and the Foundations of Mathematics … The Concept of Representation …Mathematical Machines … Human Beings as Information Processors … Levels of Reality in the Computer … Psychological Resistance to the Computer Metaphor … Some Indirect Influences of Computational Theory." (146-156.)

Baars constructed *A Cognitive Theory of Consciousness* (1988) and set forth therein "The basic model: A global workspace (blackboard) in a distributed system of intelligent information processors." (86.) There is "no central executive" in Baars' model but rather "a central information exchange that allows many different specialized processors to interact. Processors that gain access to the global workspace can broadcast a message to the entire system." (87, 43.)

Comparison of views of Baars and James shows that introspections, feelings and muscular movements discussed by James are all but absent from Baars' model. "From a scientific point of view, all evidence can be stated in entirely objective terms." "[A] useful (though not perfect) objective criterion for conscious events" thus "marks out a clear domain." "Within this domain, we can proceed with theory construction, and then consider more difficult cases. …*Verifiable, immediate consciousness report* is in fact the most commonly used criterion today." (P. 15.)

Although Baars argues that "cognitive psychologists can interpret commonsense psychological terms in a rather straightforward way," his examples for such terms, "Thought, language, knowledge, meaning, purpose, imagery, motives, even consciousness and emotion" do not reach towards muscular movements and imagery of one's own body that I call feelings. (7-8.)

Like James, Baars focuses on perception: "perception is surely the premier domain of conscious experience. Nothing else can come close to it in richness of experience and accessibility." (P. 54.) Conscious perceptions are different from imaginal experiences. "In this book we will use the word 'imaginal' to mean internally generated quasi-perceptual experiences, including visual and auditory images, inner speech, bodily feelings and the like." (P. 14.)

In contrast to perceptions, Baars relegates bodily feelings and muscular movements to "action." Like James who insisted that "*there is no proof that the same bodily sensation is ever got by us twice*," Baars teaches that "Studies of mental imagery typically look for internal consistency." (17.) "Wiggling a finger seems simple enough, but its details are not conscious the way perceptual events are, such as the sight of a pencil or the sound of a spoken word." (Pp. 63-64.) Like James, Baars derogates muscular movements, but without even the recognition of their importance provided by James. "A rough comparison of major input, output, and intermediate systems suggests that consciousness is closely allied with the *input* side of the nervous system. …the outcome of perception is a very rich domain of information to which we seem to have exquisitely detailed conscious access. By comparison, imagery seems less richly conscious, as are inner speech, bodily feelings and the like. Action control seems even less conscious… The conscious components of action and imagery resemble conscious perception." (P. 21.)

James' treatise culminates in four major chapters on "The Production of Movement." In Baars' *Theory*, a full-page Table is labeled *The major functions of consciousness* (p. 349); the only mention of action appears in the shortest entry in the list of 9 functions:

"4 *Recruiting and Control Function* Conscious goals can recruit subgoals and motor systems to organize and carry out mental and physical actions."

Commenting on another researcher's claim that actions are controlled by modules that are independently activated and that compete for control, Baars states: "This claim is consistent with a widespread conviction that the detailed control of action is decentralized or 'distributed' so that much of the control problem is handled by local processes." (Pp. 57-58.) Such local processes seem to be peripheral to the "global workspace (blackboard)."

Baars' global workspace occupies a position comparable to James' Stream of Thought with its Unity of Thought. Gone are James' bird-like "alternation of flights and perchings" where flights are like "spinning tops" that cannot be stopped for observation. Instead, in the global workspace, "conscious events and their goal contexts" have an "interplay" where a "conscious event can trigger a new goal context, which can, in its turn, evoke later conscious experiences. (Figure 6.3). We introduce a graphical notation for contexts. Competition between incompatible contexts … may lead to momentary forgetting and a resetting of the global workspace due to competition between incompatible contexts." (P. 240.) "Incompatible contexts" is Baars' approach to what James called "antagonistic representations."

Baars expressly relies on James as to modeling of "volition" or "will" ("Volition as ideomotor control of thought and action" at 246 *et. seq*.). Baars, however, focuses on information processing and not biological activity. "In *Global Workspace theory*, [informativeness is] one of the necessary conditions of a conscious event. Conscious input is always interpreted in an implicit contest of alternatives [appearing in the Global Workspace], and results in a reduction of uncertainty among those alternatives." (Definition of "informativeness" at 380.)

"How should we represent the Action Fiat Hypothesis in GW theory? If goal-images tend to execute automatically, it makes sense to suppose that timing an action involves *inhibiting execution* of a prepared action up to the right moment, and then releasing inhibition. Presumably, specialized processors sensitive to timing act to hold up execution of a goal-image until the right moment (see Figure 7-3)." (264.) Figure 7-3 has a graphical heading "Dominant Context Hierarchy" and a text caption "Implicit decision making as a vote between competing groups of processors." The "diagram describes intuitive, spontaneous, inexplicit decisions about conscious alternatives." (281.)

James' Feeling of Effort that was based in "tense muscles," etc. becomes "mental effort" for Baars, namely, the "subjective experience of resistance to current goals. Mental effort takes up central, limited capacity, suggesting that it involves the *global workspace*. … The perception of effort may be a key to the experience of voluntary control." (P. 382.)

Computers are not expressly mentioned in Baars' model but information processing is its goal and his suggested processes are congruent with computation. There is no suggestion that anything in Baars' model is beyond the capacities and competence of computers. Rather, there is an expectation that a "computational formalism … can be used to make the current theory more explicit and testable when that becomes appropriate." (43.)

I suggest that Baars' *Theory* fails to connect to actual life. As quoted above, in *The Cognitive Revolution in Psychology*, Baars wrote: "Behaviorism as an intellectual discipline forces psychologists to *distance* themselves from the everyday psychology that we all live." In my view, if Baars' Cognitive Theory stands closer than Behaviorism to everyday psychology, it is still much more distant than the position James occupied. "The Consciousness of Self" is the longest chapter in James' *Principles of Psychology* and stands in a prominent foreground position. In that chapter, in the chapter on Will and in many other places, James describes human characteristics and personalities and attempts to use his Principles to organize them in human terms. James has some excellent successes, makes many middling fits that show their age and commits a large number of overgeneralizations and other errors. Such attempts at organizing human characteristics and personalities are infrequent in Baars' *Theory* and appear as asides rather than as constitutive material. Baars recognizes the issues: "One may wonder whether the computational analogy favored by cognitive psychologists will have a dehumanizing effect as well." He evidently concludes that there is nothing to fear: "Curiously enough, the effect so far has been to humanize rather than dehumanize our scientific conception of human beings. Compared with the older perspective in psychology, cognitive psychology sees people not as passive, but as active; not as physical in some simple sense, but as information-dependent … awesomely complex organisms … reality-oriented and indeed reality-creating creatures." (414-415.)

Difference between James and Baars are not merely the result of a presence or absence of clinical anecdotes or breakfast table pontifications rendered in a 19^{th}-century style. Facts of actual life that were major topics for James have been reduced by Baars to informative states and messages. Depersonalization in the psychological domain is paralleled by a techniques in the conceptual domain that unite to strip the subject matter of references to actual human character. Forms of conscious perception are given hegemonic status and over-ride other kinds of experience, such as bodily feelings and muscular movements. Activities of consciousness are re-cast into forms that appear suitable for computation. James denied that we are automata and insisted that feelings cause movements; but there is little in Baars to distinguish human beings from automata and little note of feelings. Cause is attributed to informational processing of representations that have been broadcast through a global workspace (blackboard).

d. Models of psychology and brains aiming at computers lead to electronics designs that embody platonic principles of linearity, equilibrium and energy conservation and that fail to connect to actual life.

Modern scientific psychologies and brain models that invoke computers seek to address a chief defect in James' treatise — the wishful notion quoted above that would connect imagery to action: "For a million different voluntary movements, we should then need a million distinct processes in the brain-cortex (each corresponding to the idea or memory-image of one movement), and a million distinct paths of discharge. Everything would then be unambiguously determined…" The hypothesis of a million different connections needs to be replaced.

Advocates of artificial intelligence such as Marvin Minsky (quoted above in § 1.c) declare that principles of computation provide the desired replacement. As shown by Penrose, that position is supported, at least in major part, by principles of platonism, according to which idealized math-like structures govern everything in the Universe, including operations of brains.

Also of importance are factual errors in James treatise. James declared: "It seems to me that no evidence of the muscular measurements in question exists; but that all the facts may be explained by surface-sensibility, provided we take that of the joint-surfaces also into account." He is contradicted by modern research. According to William C. Calvin, *The Cerebral Symphony: Seashore Reflections on the Structure of Consciousness* (1990) at 84: "one of the lessons of sensory-systems neurophysiology is that the movement-directing nerves descending from brain to the spinal cord also have little branches to the ascending sensory pathways, serving to adjust sensory bias or communicate an expected sensory input from the about-to-be-ordered movement (so-called efference copy) for comparison purposes."

Calvin further states: "There's a lot of feedback from muscle tension and limb position into consciousness that affects our 'will.' … The sensory and movement systems are a good deal less independent than we originally thought; while movement-planning language may not serve as a universal description of what's going on in consciousness, it seems less prone to the tangles in which sensory-oriented descriptions land us (see the tortured debates on 'representations' in any cognitive science treatise.)" (Pp. 84-85.)

Calvin provides a view of modern brain science that is useful to me. I referred to *Cerebral Symphony* in the original *Quad Nets* paper and at http://www.quadnets.com/mechaphor.html Calvin has a special interest in muscular movements that extends from invertebrates to human beings and he observes and comments on different kinds of human movement in ways that show James' deficiencies. Thus, Calvin distinguishes slow and continuous movements that are subject to correction from ballistic movements like hammering or kicking that cannot be corrected:

"…each correction takes time because the message moves slowly along the nerves, and the central nervous system takes time to decide too. A minimum round-trip loop time for arm-back-to-arm movements in humans is 110 milliseconds." (pp. 238-243.) The notion of ***training*** pervades Calvin's book but is all but absent from James' long treatise, where it appears in such clumsy forms as an instinct for collecting or as a way to derogate bodily feelings, as quoted above ("the more practised we become in a movement, the more 'remote' do the ideas become which form its mental cue").

In *Cerebral Symphony*, Calvin is meditating on means of construction of models rather than proposing a disciplined model. His contemplated means are common in scientific psychologies, e.g., principles of darwinism and computation. However, he is also apparently skeptical of some other popular concepts, such as representations in cognitive psychology, as quoted above. He considers critical perspectives, e.g., "Cause-and-effect reasoning sometimes isn't very good when it comes to open systems with energy to spare." (P. 152.) Energy ***dissipation*** (similar to that of systems with "energy to spare") is important in my brain models, in contrast to models that depend on energy ***conservation***. In a similarly helpful way, Calvin quotes neurobiologist Graham Hoyle: "What you've got to realize is that every cell in the nervous system is not just sitting there waiting to be told what to do. It's doing it the whole darn time. If there's input to the nervous system, fine. It will react to it. But the nervous system is primarily a device for generating action spontaneously. It's an ongoing affair. The biggest mistake that people make is in thinking of it as an input-output device." (P. 314.)

Notwithstanding such helpful material, when he discusses proposed constructions, Calvin generally neglects bodily feelings. Rummaging in the index to *Cerebral Symphony* discloses no entries for "feelings" and 15 entries for "feedback." References to "body-image" and to "sensory" matters are meager. In contrast, there are long lists of entries under topics relating to movements, to computers and programs, and to darwinism and evolution.

Calvin's proposal to connect imagery to action is an elaboration of James' ideo-motor action that does not resolve its chief problems. Calvin rejects James' simple-minded hypothesis of a million automated connections. According to Calvin (p. 143): "Expecting a specialist cell (or 'labeled line') for each schema (Marvin Minsky, take note) is called the *Grandmother's face cell fallacy* by neurophysiologists." Like James, however, Calvin views muscular movements as a product of mental operations and presumes, as a foundational concept, that mental operations determine movements prior to the commencement of movement. Then, adjustments, to the extent they are possible, are determined by "feedback." "THE TRIAL AND ERROR CONCEPT" is a chief principle. (P. 259.) Calvin's approach may be suited to certain activities, such as throwing a stone at a rabbit (pp. 242-251) but generalization to "movement melodies" and to global brain models is openly speculative. (Pp. 251-273.)

In dealing with the focal problem of connecting imagery to action, Calvin maintains the primacy of "sensory processing" in a direct "sensation-to-movement transformation."

"It is only very simple motor programs with simple spatiotemporal patterns of muscle activity that can get by with the "Model A" approach to orchestration. The appropriate trigger for most motor programs is going to be a keylike correct *combination* of triggers in many cells; indeed, it will probably be just as important *which cells are inactive* as which are active. Therefore, one expects the ultimate stage in sensory processing to produce a pattern as the trigger. And it's not just a spatial pattern like the key notches: It is a spatio*temporal* pattern, like the fireworks finale, the *order* in which various neurons are activated, as well as *which* neurons are activated, being the key.

"The sensation-to-movement transformation is many-to-many; and there is no need for a many-to-one bottleneck unless the one cell has some special advantage for producing the spatial or temporal aspects of the movement subcommands … [¶] PATTERNS AS THE DETERMINANT, rather than absolute quantities of some thing, are also a big feature of growth and development. …" (P. 148.)

Determinant patterns, according to Calvin, are produced by machinery that operates according to principles of darwinism: first, the machinery generates "guesses" and then it removes bad ones. "A Darwin Machine now provides a framework for thinking about thought, indeed one that may be a reasonable first approximation to the actual brain machinery underlying thought." No Darwin Machine exists, even in designs, but such a Machine is expected to correct problems with present computers. Calvin contemplates "massively parallel selection among stochastic sequences [that] is more analogous to the ways of darwinian evolutionary biology than to the 'von Neumann machine' serial computer. Which is why I call it a Darwin Machine instead; it shapes up thoughts in milliseconds rather than millennia, and uses innocuous remembered environments rather than the noxious real-life ones." (Pp. 261-2.)

Calvin foresees a developmental path from his present positions to the desired goal of a conscious and imaginative robot.

"Neurallike networks, once they become capable of generating randomly varied sequences, then successive selections by remembered environments, do offer an obvious route to machine intelligence and intelligent robots—though, should we succeed, we shall surely have to cope with machine imagination and machine 'free will.' " (P. 314.)

"how to build a conscious robot can now be glimpsed; it falls out of scenario-spinning considerations, out of Darwin Machines, out of neurallike networks…" (P. 322.)

Calvin's "conscious robot" is a puzzling verbal juxtaposition of "consciousness" and "robot," consisting like "free will" in an arranged marriage between two terms which do not fit each other. There are no "conscious robots" in actual life, as far as I know.

Christof Koch pursues a different path in *The Quest for Consciousness: A Neurobiological Approach* (2004). He propounds the question: "Why, then, from the point of view of evolution, does consciousness exist? What survival value is attached to subjective, mental life?" (page 2.) Koch's answer is that consciousness is "a powerful and flexible system" that "evolution chose … to deal with the unexpected and to plan for the future." (317-318.)

As part of Koch's answer, he proposes ***zombie agents***. The zombie agent explains muscular movements without the need for feelings. "In philosophy, a *zombie* is an imaginary being who behaves and acts just like a normal person, but has absolutely no conscious life, no sensations, and no feelings." (*Id*.) Although he dismisses philosophical concepts of zombies as "sterile," Koch uses the zombie word for behavior that he considers non-conscious. (205-216.) We act like zombies when we perform "relatively complex sensory-motor behaviors" that are "rapid and unconscious. Indeed, the point of training is to teach your body to quickly execute a complex series of movements… Nonconscious processing extends to the highest echelons of the mind… Much high-level decision making and creativity occurs without conscious thought….” (3.)

Thus, Koch declares that “neurophysiologists have inferred the existence of *zombie agents* in the brain that bypass awareness…” (3.) Something like zombie agents control “Balancing the Body.” (208.) Such “nonconscious agents control head, limb, and body posture” when “you weave your way through crowds of shoppers on the sidewalk.” They receive “continually updated information from many modalities, not just vision. The inner ears supply head rotation and linear acceleration, while myriad motion, position, and pressure sensors in the skin, muscles, and joints monitor the position of the body in space.” (*Id*.) A baseball player engaged in fielding practice “is actively wiring up a zombie agent.” (236.) “When you want to run along a trail, you ‘just do it.’ Proprioceptive sensors, neurons, and the muscular-skeletal system take care of the rest, and you’re on your way. Try to introspect and you’ll be confronted with a blank wall. Consciousness has no access to the amazingly complex sequence of computations and actions that underlie such a seemingly simple behavior.” (317.) “A disconcertingly large fraction of your everyday behavior is zombie-like: You drive to work on autopilot, move your eyes, brush your teeth, tie your shoelaces, greet your colleagues in the hall and perform all the other myriad activities that constitute daily life. Any sufficiently rehearsed activity, such as rock climbing, dancing, martial arts, or tennis is best performed without conscious, deliberate thought.” (318.)

Zombie agents seem much like the automata rejected by James or like robots that need no consciousness. According to Koch, however, there are some functions that zombie agents cannot perform and these are assigned to consciousness. “Why, then, isn’t the brain just a large collection of specialized zombie agents? Life might be boring if it were, but since agents work effortlessly and rapidly, why is consciousness needed at all? What is its function? … I argue that consciousness gives access to a general-purpose and deliberate processing mode for planning and contemplating a future course of action.” (3-4.)

In Chapter 14, “Some Speculations on the Functions of Consciousness,” Koch explains “WHY THE BRAIN IS NOT JUST A BUNDLE OF ZOMBIE AGENTS.” He considers the possibility that “the organism would come out ahead if the slower, conscious planning state were replaced by nonconscious agents. The disadvantage would be the lack of any subjective, mental life. No feelings whatsoever!” (237.)

On the other hand, Koch suggests that consciousness somehow overcomes the problem of a “million different” connections that was noted in connection with James’ model. “Given the many senses—eyes, ears, nose, tongue, skin—that flood the brain with information about the environment, and given the diverse effectors controlled by the brain—eyes, head, arms and fingers, legs and feet, the trunk—breeding zombie agents for all possible input-output combinations is probably insufficient. Too many would be required…” (*Id*.)

Koch views consciousness as a function distinct from muscular movements produced by zombies. The computational “Turing Test offers a practical means to gage progress in designing intelligent machines. A similar operational means to distinguish automatic zombie behaviors from those that require consciousness would be desirable.” Koch suggests that “litmus tests” that are part of a “battery of operations might distinguish automatic from conscious behaviors.” (232.)

It thus appears that, for Koch, brain functions divide into automatic and conscious kinds. I suggest that Koch’s automatic zombie agents do not fit together with materials on “Attention and Consciousness” discussed in Chapter 9, e.g., discussions of attention directed at salient objects, selective attention or "looking at," searching attention or "looking for" and "Doing Two Things at Once." (153-171.)

Specifically, Koch's investigates "The Neuronal Underpinnings of Attention" in Chapter 10 (173-185) and starts with "Mechanistic Accounts of Attention." (174-178.) Mechanisms provide models for one chief function of attention (biasing competition among coalitions of neurons, e.g., during decision-making) but not for a second chief function, namely "to dynamically bind attributes of unfamiliar objects." (184.)

"Binding" is a major issue in neuroscience and especially for Koch. The ***binding problem*** is raised by modern technologies of neuroimaging (fMRI, PEET, tomography, etc.) that enable scientists to observe operating brains in living persons and animals. The observations show that a brain is made up of hundreds or thousands of specific anatomical regions and that each such region has a variable activation, identified by a variable blood flow carrying sugar that fuels activities. Regions that have a high level of activation at a given time are involved in the momentary activity of the brain. Regions that have a low level of activation are not involved in such activity but appear to be resting. Any particular task or situation requires activation of a particular combination of regions and the combination changes when the task or situation changes. Performing a task of hand-eye coordination requires a combination of brain regions that is different from combinations required for adding numbers mentally or listening to music.

Brain regions that are highly activated and engaged in a particular task are typically scattered throughout the brain. To perform a task requiring hand-eye coordination, a region in the forebrain apparently involved in planning is activated, along with regions in the temporal lobe that are involved in vision and regions near the bottom of the brain, the basal ganglia and the cerebellum, that control muscular movements. [Rough estimates suggest 1 billion neurons in the spinal cord, 70 billion neurons in the cerebellum and 12 to 15 billion neurons in the cerebral regions.] Coordination of hand and eye requires coordination of widely-scattered brain parts. Because of the variability of tasks and in light of actual smooth changes of coordination during some tasks, coordination of brain parts must be highly flexible and adjustable. That is, activities of different brain regions must be "bound together" in flexible ways. The question of "how to" bind together different brain regions in flexible ways is called the "binding problem." The binding problem presents much the same question as free-will puzzles, namely, how to connect imagery to action. The binding problem is a fruitful form of the question, in contrast to "free will," which has proved fruitless.

Koch and Francis Crick, Koch's mentor, have helped to develop an approach to the binding problem, namely, the concept of "[b]inding via neural synchrony." (168, n. 33 and 169.) [James noted that theoretical and experimental researchers had argued: "the physical condition of consciousness being neural vibration, the consciousness must itself be incessantly interrupted by unconsciousness - about fifty times a second." (Chapter VIII, fn. 1.) As discussed below, Shimmering Sensitivity operates via neural synchrony and binds through non-local reach.]

Koch's classes of zombie agents and conscious bindings do not fit together. Memory operations show the misfits. Koch suggests that we "think of [zombie behaviors] as cortical reflexes." "Zombie agents operate in the here and now, so they have no need for short-term memory. … Force the organism to make a choice, such as inhibiting an instinctual behavior, following a delay of a few seconds. If the creature can do so without extensive learning, it must make use of a planning module that, at least in humans, is closely linked to consciousness." (319.)

As Koch discusses in Chapter 11 “Memories and Consciousness” are interdependent. He identifies distinct forms of memory — short-term, long-term, associative and non-associative, procedural and declarative, as well as fleeting or iconic memory, which is an “even briefer form [that] is probably essential to conscious experience. (187-204.)

In sum, it appears that Koch separates automatic functions from conscious functions, with corresponding brain operations identified as zombie agents on the one hand and binding via neural synchrony on the other hand. Unfortunately, the two tools do not operate together or provide connections between images and action. Zombie agents refer to muscular movements and seems to have a local character while neural synchrony refers to global generation of images. No way is shown to go from one to the other. Zombie agents appear to be excluded from forms of memory and consciousness that often seem to control muscular movements. Long-term memory and procedural memories are essential to trained and skilled performances.

Koch admits that his proposals are “hardly very rigorous.” The difficulties do not daunt him. “At this point in the game, it is too early for formal definitions.” (319.)

Compared to actual life, “nonconscious processing” by zombie agents does not fit my actual experience. I cultivate my consciousness of muscular movements and bodily feelings “in the here and now” through practices of yoga and qigong (chi gong). Martial artists and body-discipline practitioners write meaningfully about such consciousness. Practices typically involve repeated movements and positions according to “forms” that are taught by experts. It is through repetition of such forms that particular instances of consciousness are identified. A chief feature of such practices is the binding together of movement and feeling within the form.

As set forth on the first page of this essay, I suggest that your body is exercising freedom when “you weave your way through crowds of shoppers on the sidewalk.” Koch wants such activity to be performed by unconscious zombie agents. However, he provides no “means to distinguish automatic zombie behaviors from those that require consciousness.” You can weave consciously or unconsciously. Probably you can weave faster consciously, especially if you are very tall.

When I introspect, I find, not Koch’s “blank wall,” but a body full of feelings that occur regardless of introspection or awareness. I can play with such feelings. For example, I look at a small object on my desk. Then, after closing my eyes, I reach out and grasp it, guided by feelings in my arm and fingers and by memories of the visual image. If my aim fails to find the object, I can grope around on the desk. I can extend my play with such introspective “ideo-motor” exercises to the kitchen, where purposeful cleaning, preparation and slicing of vegetables adds to the ideo-motor repertoire and introspections thereof.

Koch’s references to zombies, like those of Calvin to robots, seem to me to reflect systematic biases in scientific psychology against recognition of bodily feelings. “Zombies” are creatures in film fantasies. The notion that they balance and walk with “no sensations[] and no feelings” is contrary to my experience of actual life. I suggest that scientific bias against bodily feelings extends to denial of individual personalities. I suggest that personality is shown in skills and styles of performances of “rock climbing, dancing, martial arts, or tennis.” Such ***spontaneous trained*** performances are fully conscious; the performer’s movements are typically a product of deliberate planning and deliberate execution —contrary to Koch’s assertion that they are “best performed without conscious, deliberate thought.” When I set out to climb a big steep rock, for example, I typically visualize places for steps along an anticipated route before I start moving.

Visualization is easier and more effective when I am climbing up, compared to when I am climbing down. I am bolder climbing up and more timid climbing down.

In his investigations, Koch focuses on sensory processing. "Perceptual neuroscience has advanced to such a point that reasonably sophisticated computational models have been constructed and have proven their worth in guiding experimental agendas and summarizing the data. ¶ I therefore concentrate on visual sensations or awareness. [Another researcher] refers to such sensory forms of awareness as *core consciousness*, and differentiates these from *extended consciousness*. … My research program neglects, for now, these and other topics [involving extended consciousness] such as language and emotions." (15.) "I assume that consciousness depends on what is inside the head, not necessarily on the behavior of the organism." (17.)

Although Koch concentrates on visual perception, he gives little consideration to muscular movements involved in vision such as focusing on objects at a certain distance or saccadic eye movements discussed above in connection with An Eye for Sharp Contrast. Only retinal patterns seem to be important. "To extract the target location, its relative position on the retina needs to be converted into a form that the neuronal network underlying reaching, grasping, and pointing can exploit to direct the eyes, head, arms and fingers." (145.) Section 3.7 is titled "EYE MOVEMENTS: VISUAL SACCADES ARE UBIQUITOUS," but, for Koch, saccades are mostly activity to ignore. "The stability and sharpness of the visual world during eye movements is a consequence of numerous processes, including *saccadic suppression*, a mechanism that interferes with vision during eye movements. … Why, then, isn't everyday vision characterized by annoying blank periods? This must be prevented by some clever, *trans-saccadic integration* mechanism that fills in these intervals with a 'fictive' movie, a composite of the image just before and after the saccade. The mechanisms and neuronal sites of this integration remain largely unknown." (65.)

Koch's model is designed to fit principles of computers. As noted above, he assimilates zombie agents to computers. He also states: "Much data suggest … that neurons are sophisticated computational devices, and that the exact time of occurrence of spikes is important." (38.) In an earlier monograph, *Biophysics of Computation: Information Processing in Single Neurons*, Koch begins page 1: "The brain computes! This is accepted as a truism by the majority of neuroscientists engaged in discovering the principles employed in the design and operation of nervous systems. What is meant here is that any brain … performs a very large number of ill-specified operations, frequently termed computations… The outcome of some of these computations can be stored for later access and will, ultimately, control the motor output of the animal in appropriate ways."

Koch expressly pursues a computational approach and goals. "Today, much of our thinking about the brain is dominated by our favorite new artifact, the digital computer." (1.) "Thinking about brain-style computation requires a certain frame of mind, related to but distinctly different from that of the biophysicist. … we must be concerned with both aspects, with biophysics as well as computation." (xix.) He seeks to identify "biophysical mechanisms implementing specific operations that have been postulated to underlie computation." (2.)

The final chapter of the monograph is titled "Computing with Neurons: A Summary." Koch compares a brain to a paradigmatic computer or "finite state machine" and asks "to what extent can brains be treated as *finite state machines* or *automata*?" The answer is "an ambiguous 'it depends.' " (469.) The "yes" branch of the ambiguity is weak, at least initially: "finite state machines will be relevant (although not sufficient to understand[)] … how operations carried out by nervous systems, such as associative memory or visual object recognition, can be implemented in machines…" In contrast, the "no" branch of the ambiguity is strong: as to biological processes like "probabilistic synapse release, finite state machines and their relatives will not be useful for a number of reasons. The most obvious is that these virtual machines are disembodied entities … in the real world, space, time, and power are in short supply … None of these considerations are incorporated into our current notion of computation." (470.)

Despite ambiguity, "[o]n the positive side" Koch has much he "can say about the manner in which the nervous system processes information." In his advanced model: "Individual neurons convert the incoming streams of binary pulses into analog, spatially distributed variables, the postsynaptic voltage and calcium distribution throughout the dendritic tree, soma and axon. These appear to be the two primary variables regulating and controlling information flow, each with a distinct spatio-temporal signature and dynamic bandwidth. … Information is processed in the analog domain, using a menu of linear and nonlinear operations. [Specific math-like functions] are the major operations readily available in the dendritic cable structure augmented by voltage-dependent membrane and synaptic conductances. [¶] This is a large enough toolkit to satisfy the requirement of the most demanding analog circuit designer." (*Id*.)

I suggest that technical terms used in the preceding statement and in Koch's model of a neuron make up a structure that is designed to fit platonic principles. To start, a neuron is modeled as an isolated and distinct cell, detached both from its environment and also from connections to anything other than fellow neurons. The neuron is organized like an input-output machine with a central soma that receives input from fellow neurons through synapses in the dendritic tree and that discharges output through the axon and thence to synapses on other neurons. The distinct parts operate separately and have no unitary function based in or involving the whole body. For example, computational functions are attributed to the dendritic tree.

Koch's model has a platonic foundation in the "Linear Cable Theory" (25-48) which supposedly governs behavior of the neuron. Summing up his constructions based on Linear Cable Theory, Koch states: "Throughout this book, we have lived with the convenient assumption that the three-dimensional arrangements of synapses, dendrites, axons and cell bodies do not matter and that all neurons can be reduced to sets of one-dimensional cylinders. This simplification is a powerful one since it allows us to study the spatio-temporal distribution of the membrane potential and calcium distribution with ease on the basis of one-dimensional cable and diffusion equations." (459-460.) In this construction, "an entire class of dendritic trees can be reduced or collapsed into a single equivalent cylinder." (57.)

In Koch's approach, action potentials impinge through synapses onto the dendritic tree of a neuron and induce the soma to discharge new pulses through its axon. The model is expressed in equations, which "[f]rom a mathematical point of view … constitute a *singularly perturbed system*, in which one variable evolves much faster than the others. Other instances of such systems are the Hodgkin-Huxley and the Fitzhugh-Nagumo equations." (271.)

I suggest that such a "singularly perturbed system" is made up of an equilibrium "empty space" that has superimposed on it certain kinds of particulate disturbances. A particulate disturbance occurs as a distinct transient phenomenon in a fixed environment. Such a disturbance is narrowly confined in space and time, has a well-defined direction and velocity and can lead to similar disturbances in other, similar systems through point-contact interactions such as synapses.

This is an "atoms in a void" model, the desired goal of platonic physics. Such models have important uses but they have been found to be limited.

The Hodgkin-Huxley model is the primal scientific model for singular perturbations in neurons. "The Hodgkin-Huxley 1952 model of action potential generation and propagation is the single most successful quantitative theory in neuroscience." (171.) It is "[t]he cornerstone of modern biophysics." (212.) However, the equations in the model "do not capture—nor were they intended to capture—a large number of biophysical phenomena, such as adaptation … or bursting… Moreover, the transmission of electrical signals within and between neurons involves more than the mere circulation of stereotyped pulses. These impulses must be set up and generated by subthreshold processes." (*Id*.)

Limitations in the Hodgkin-Huxley model lead Koch to construct his advanced model. ("Beyond Hodgkin and Huxley: Calcium and Calcium-Dependent Potassium Currents.") "What are some of the important functional properties shared by all calcium conductances? Most importantly, the associated calcium current is always activated by depolarization…" such as depolarization that occurs during pulse propagation. (213.) Calcium currents have functions additional to pulse propagation. "The calcium concentration inside the cell not only determines the degree of activation of calcium-dependent potassium currents but—much more importantly—is relevant for determining the changes in structure expressed in synaptic plasticity. As discussed in Chap. 13, it is these changes that are thought to underlie learning." (248.) Another suggested function is to produce more complex signals than single action potentials; Koch proposes a model for ***bursting*** that includes a long-lasting action potential of relatively small size, on which rides a series of large but quick spikes.

Based on the foregoing analysis, I suggest that, as an exemplar of the science, Koch's model illustrates an "atoms in a void" approach, even when further developed to include calcium currents. The approach is purposefully directed towards goals of discovering and articulating brain operations that can be said to resemble those of computers.

A critical review suggests that, despite great efforts and ingenuity, Koch and other modelers fail to reach their computational goals. Invoking models of various researchers, Koch is able to identify "*Many Ways to Multipl*y. (471.) Such ways range from specific examples of claimed computation in the visual system of a locust to theoretical summation of a population of noisy neurons. (471-72.) Although Koch originally "was motivated by the hope that a handful of biophysical computations would be universal," he now concludes that there are "A Large Number of Biophysical Mechanisms for Computation" and identifies about 20 such computations that occur as quickly as 1 millisecond and as slowly as a second.. (473-475.) No general model, including Koch's own, works for more than a few of the examples.

In light of speculative possibilities, Koch considers "the unsettling but quite plausible scenario in which any one computation is carried out using a plurality of mechanisms at different spatial and temporal scales … any one computation would be implemented by the linear or nonlinear superposition of a host of biophysical mechanisms, where the coefficients specifying the contribution that each mechanism makes vary from one animal to the next." (474.) Moreover, as "was discussed extensively in Chap. 5: the dendritic tree geometry, coupled with a unique synaptic architecture, implements specific computations. Although this hypothesis is by now almost two decades old, we still do not know to what extent individual synapses [] or groups of them [] are involved in such computations or whether the location of synapses in the tree is pretty much irrelevant." (479.)

Throughout his constructions, Koch applies methods of platonic science in furtherance of computational goals. Outstanding themes are: (1) conservation principles; (2) linear designs; and (3) models that use electronics components.

The most serious criticism of models presented by Koch is directed at the modeling of energy. Energy generation in the models is embodied in direct current batteries; and energy storage in the models is embodied in electrostatic fields in capacitors. Electrostatic fields are maintained by batteries in a foundational equilibrium condition that may be briefly perturbed but which is quickly restored. Such a model seems easy to fit to views that see computers operating with digitalized states but is hard to fit to views of thermodynamics that see constant energy flows in blood sugar, dissipative processes and a multitude of phase changes in material bodies, to views of biology that see energy storage in chemical bonds and a seething ocean of interactive biochemical activity, or to views of actual life that see continual streams of new experiences and transformations. I suggest that highly variable ongoing activities like those seen in brains will not be usefully modeled by equilibrium electrostatic fields maintained by DC batteries.

Koch introduces electronics components – resistance "R" and capacitance "C" – in a section titled "RC Circuits as Linear Systems." "Linearity is an important property of certain systems… the issue of linear and nonlinear systems runs like a thread through this monograph…" (12.) Resistances are governed by Ohm's Law, introduced above as a linear relation. A similar linear relation governs a capacitance. Using such components, Koch presents a model of the ***Linear Cable Equation*** in "**A Single Passive Cable** Equivalent lumped electrical circuit of an elongated neuronal fiber with passive membrane. The intracellular cytoplasm is described by an ohmic resistance per unit length r_a and the membrane by a capacitance c_m in parallel with a passive membrane resistance r_m and a battery V_{rest}." (30-31.)

Koch recognizes that the linear cable theory model is limited: "it could be argued that studying neurons under such constraints will fail to reveal their true nature. However, it is also true that one cannot run before one can walk, and one cannot walk before one can crawl. … one first needs to study the concepts and limitations of linear cable theory before advancing to nonlinear phenomena." (26.)

The linear cable theory model provides the "void" in which particulate signals move. "From the point of view of information processing, a linear noiseless system cannot create or destroy information. Whatever information is fed into the system is available at the output. Of course, any system existing in the real world has to deal with noise… Therefore, in a noisy, linear system, information can be destroyed. But what is needed in a system that processes information are nonlinearities that can perform discriminations and decisions. Similarly, … for a digital system … a nonlinearity … is required." (19.)

In Koch's brain model, nonlinearities are provided by synaptic input. (*Id.*) Only certain kinds of synaptic inputs are considered and Koch's selections of synaptic inputs target computational goals. "Synapses are the elementary structural and functional units for the construction of neuronal circuits. Conventional point-to-point synaptic interactions come in two different flavors: *electrical synapses* .. and the much more common *chemical synapses*." (14-15.) "It is useful to distinguish fast ionotropic chemical synapses, acting on a millisecond time scale, from metabotropic chemical synapses, acting on a time scale of a fraction of a second to minutes." (115.) "[F]ast chemical synapses [are] the stuff out of which computations arise." (24.)

The neglected "electrical synapses are frequently found in neuronal pathways which subserve information that needs to be communicated very rapidly and faithfully. In the retina, gap junctions … create vast, electrically interconnected networks…" (116) In the heart: "Gap junctions allow single action potentials, originating in a group of pacemaker cells, to sweep through all cells in a wavelike manner, generating the rhythmic squeeze and relaxation that is the stuff of life." (113.) "*Ephaptic transmission* refers to nonsynaptic electrical interactions. … Their functional significance—if any—is not known and we will not discuss them here." (85) Around a dendritic tree, however, "this type of ephaptic coupling could be of functional relevance, yet almost no theoretical work has been carried out on this subject." (29.) "Glial cells are another example. These cells, thought to play mainly a supporting metabolic role … lack conventional chemical synapses. They communicate instead via an extensive grid of electrical gap junctions with each other." (113.)

Fast electrical couplings and slow chemical couplings are apparently not needed for computation. "Conceptually and *cum grano salis*, ionotropic synapses are the essence in the rapid forms of neuronal communication and computations underlying perception and motor control." (115.)

Nonlinearities are essential to information processing and are provided by the Hodgkin-Huxley model, but linear models are easier. "Although it can be argued that a linear analysis of a nonlinear phenomenon does not do justice to it, it will certainly help us to understand certain aspects of the mechanism underlying the phenomenon." (245.) In further modeling, Koch linearizes the Hodgkin-Huxley equations, the potassium current, the sodium current, and the membrane impedance (resistance) of a patch of squid axon. (232-247.)

Koch incorporates other platonic features of current brain models: (1) generalization from experiments performed on the giant axon of a squid with a "so-called *space clamp* [that] keeps the potential along the entire axon spatially uniform" (144) — the Hodgkin-Huxley "model is based on voltage- and space-clamped data" (161) — "Indeed, action potentials [in other animal experiments] do not show any hyperpolarization, unlike those of the giant squid axon" (165); (2) homogenization of the environment in models ("The extracellular space is reduced to a homogeneous resistive milieu" – p. 47); (3) Kirchoff's current law, suitable for electronics components but not for electro-chemical processes in living organisms (Pp. 9, 17, 30, etc. — likewise, James wrote: "The currents, once in, must find a way out."); (4) compartmental modeling, "a system of … equations, corresponding to small patches of neuronal membrane that are ***isopotential***…" (60, emphasis added, identifying quasi-static elements).

Koch's brain models aim to show how brains are computers. He applies methods of platonic science with skill and ingenuity. My conclusion, however, is that the results are meager. Although the constructions are carefully shaped and directed toward the computational target, the target is not reached. Actual computations are few and far between and no general conception unites or organizes them. There is little in such computational speculations to suggest how action is caused or to connect proposed models to action and there is little to suggest applications to actual life.

6. In new alternative constructions, "beats" of actual life, along with wags of a Dogtail, are modeled by movements of muscle-like modules. Temporal forms based on such movements include episodic balancing forms that are embodied in new technologies as Shimmering Sensitivity, a principle of freedom, and that also govern sports competitions and jury trials. Outcomes of such events often turn on personal efforts and personal decisions that occur during transformational critical moments.

Critical analysis of the "modern scientific view" in § 4 shows that such a view is based on a set of spatial forms and on successes in applying those forms to certain phenomena, beginning with spheres moving solely under the influence of gravity in empty space and similarly idealized pV=RT relations of a dilute gas in a closed container. Methods developed for the inherent symmetries of empty space were extended into other domains that could be similarly symmetrized. Building on such paradigms, scientific forms have been successfully applied to numerous phenomena and have been embodied in wonderful technologies.

Such successes have encouraged a presumption that scientific forms describe and control all phenomena, e.g., phenomena of brains, as discussed in § 5. The presumption has focused investigators on sensory perception and has excluded or derogated large classes of phenomena, especially muscular movements and related bodily feelings. I suggest that systematic biases arising from scientific forms shape research programs and the professional consensus.

For some persons, successes of science and technology justify a hegemony of scientific forms. Such persons say that the modern scientific view is superior to all other views. Advocates declare that scientific forms apply to each and every situation. They hold that any clash of views must be resolved in favor of a scientific view. It is said that platonic forms of logic embodied in computers also describe and control activities of brains and thus all activities of actual life.

I suggest that claims of scientific hegemony are not supported by facts. The facts are that personal freedom and consciousness are important in actual life and that scientific and platonic forms fail to describe freedom or consciousness. Scientists claiming hegemony often belittle freedom and consciousness. In actual life, however, personal disputes and other personal matters cannot be handled by reference to "impersonal invariants" or Laws of Physics but must be resolved through exercises of freedom and powers of consciousness. As a matter of fact, scientific principles have had little practical application to social or institutional problems despite enormous research efforts. Few scientists have occupied positions of importance in the actual histories of nations or peoples.

My approach is to construct a new set of temporal forms that are different from the spatial forms of platonic science. I suggest that new temporal forms can be embodied in new technologies. I suggest that models to be built from new technologies will more closely mimic activities of animals that have actual life and of human institutions that are built on foundations of actual life. I suggest that development of such models can lead to improved forms for use in social, legal and political institutions.

a. The beat is a primal temporal form in new models of actual life.

Ancient Hebrew culture sharply contrasts with ancient Greek culture and platonic science. According to T. Boman, *Hebrew Thought Compared with Greek* (1960): "the thinking of the Greeks is spatial and that of the Hebrews is temporal. … Greek and Israelite-Jewish interpretations of time are entirely different." (p. 20.)

In Boman's constructions of ancient Hebrew Thought and ancient Greek Thought, each Thought had a distinct character. The constructions grew out of academic studies of diverse Jewish and Greek source materials used by early Christians in constructing their new religion, as reflected in diverse scholarly views. (*Id*., 20-21; Schweitzer; Pelikan; Dodd, 74-75.)

Boman's constructions are useful in my approach because they provide context for new temporal forms. Spatial forms of platonic science have references in ancient Greek culture; temporal forms of new proposed technologies can be referred to ancient Hebrew culture.

In his "Summary and Psychological Foundation of the Differences," Boman states (205): "The Greek most acutely experiences the world and existence while he stands and reflects, but the Israelite reaches his zenith in ceaseless movement. Rest, harmony, composure, and self-control—this is the Greek way; movement, life, deep emotion and power—this is the Hebrew way."

"According to the Israelite conception, everything is in eternal movement: God and man, nature and the world. The totality of existence, '*ôlam*, is time, history, life." (*Id.*)

As discussed above, new proposed models of actual life are based on muscular movements. Every muscle is activated and ready all the time, maintaining tonus even when immobile. Actual muscular movements arise out of readiness. The underlying basis of all mental activity is a plenum of muscular activation. I suggest that movement, activation and readiness resonate with Hebrew Thought while invariance, symmetry and equilibrium resonate with Greek Thought.

Focusing on specific temporal forms in Hebrew Thought, Boman states: "The shortest span of time, or Hebraically expressed, the shortest perception of time, is *regha*'–a beat, or as von Orelli so suitably suggests, the pulse-beat of time." "[T]he Hebrew *regha*' refers to some sort of bodily sensation such as pulse-beat, heart-beat, or twitching of the eyelid. In any case, the shortest time in Hebrew is not a point, nor a distance, nor a duration, but a beat." (136.)

In models of actual life, ***the beat*** is a primal form of movement, a form that can change with the situation and that can develop into variant beat forms. Variant beat forms can combine in waves and cycles suitable for coordination and organization. The primal beat is the thump-thump-thump of a heart, the tap-tap-tap of a musician's foot, the step-step-step of marching and the "push, push, push" that is the only activity of a jellyfish. (Walter, 18.)

Boman states: "In *regha*' there is originally something violent." Compared to other words, "*regha*' is more the rapacious, violent, stormy suddenness with which something takes place," e.g., when fish and birds are "suddenly ensnared" (Eccles. 9:12) or when a man is "straightaway" overcome by sexual temptation (Prov. 7:22). Several Hebrew words "are used like *regha*' to designate abruptness." (137.)

In the genre of horror and suspense films, directors use an audio beat in a characteristic way that conveys a "rapacious, violent, stormy suddenness" — or, more precisely, the beat is signaling that such a suddenness is about to occur. The scene on the screen may be banal, a person walking slowly towards a house, for example; meanwhile, the sound track carries a strong beat with a character like that of a heartbeat. The beat signals an impending suddenness. The beat in the horror film is pregnant with approaching action that will be rapacious, violent or stormy.

In my approach, a beat is pregnant with multiple possible movements that may suddenly appear and that may range from rapacious violence to delicate sensitivity and even to stillness and silence. What suddenly appears may be transformational but there will also be conserved a character that is grounded in history and memory. The beat is not just signaling that something happened in the past or that something will be happening soon: the beat is a continuing beat that potentially unites past, present and future in movement that extends without limit.

A distinction between smooth action and jumpy or sudden action is important in constructions developed below. The two kinds of action turn into two kinds of control. One kind of control is ***continuous control*** and that other is ***saccadic (jumpy) control***. Continuous controls fit forms of platonism that incorporate the continuity of geometric space; saccadic controls operate according to principles of discontinuity. "Abrupt" connotations of *regha*' are suggestive of saccadic controls. The suggestion is rooted in facts of actual life, where sudden or jumpy action often seizes control from smooth action. Jumpy, abrupt, even violent action is often a more powerful influence in actual life than smooth action based on reason — and such power is in surprising suddenness and in the size of jumps.

Another major temporal form in Hebrew Thought is "purely and simply a rhythmic alternation," e.g., "seedtime and harvest, cold and heat, summer and winter (Gen 8.22)." (Boman, 134.) "An isolated unit of time, therefore, has a rhythm which for the sake of comparison with rhythmic speech can be given the form: unaccented—accented—unaccented, or to compare it with the pulse-beat, weak—strong—weak. Thus in Hebrew the period of day and night is a rhythm of dull—bright—dull; evening—morning—evening (Gen. 1.5, 8, 13,19, 23, 31.)" (135.)

In ancient Israel, rhythms were forms of actual life. The weekly day of religious observance, the sabbath, had first importance. (Deut. 20:8-11.) Each year was organized through festivals and observances. (*Id*., 34:18-23.) "A longer period of time is thought of as a continued rhythm passing over into a higher time-rhythm, etc. The shortest rhythm, the day, passes over into the week-rhythm, then into the month-rhythm, and then into the rhythm of the year…The seven-beat rhythm of the week is continued in the sabbath year and the jubilee year." (Boman, 135-136.)

Rhythmic forms of actual life were famously set forth in Eccl. 3:2-8 (140-141):

> "A time to be born and a time to die;
> A time to plant and a time to pluck up that which is planted;
> A time to kill and a time to heal;
> A time to break down and a time to build up;
> A time to weep and a time to laugh;
> A time to mourn and a time to dance;
> A time to cast away stones and a time to gather stones together."

"As space was the given thought-form for the Greeks, so for the Hebrews it was time." (206.) "For us space is like a great container that stores, arranges, and holds everything together; space is also the place where we live, breathe, and can expand freely. Time played a similar role for the Hebrews. Their consciousness is like a container in which their whole life from childhood on and the realities which they experienced or of which they had heard are stored." (137.) In contrast to the linear form of Greek time, for the Hebrew, “time is determined by its content.” (124-125, 131.) “[I]n the Indo-European languages, the future is quite preponderantly thought to lie before us, while in Hebrew future events are always expressed as coming after us.” (130.)

Hebrew Thought is built around time but “time is assessed by Plato as well as by Aristotle as something vastly inferior to space, partly as an evil. Aristotle is in agreement with the maxim that time destroys…nothing grows new or beautiful through time…everything pertaining only to space, e.g., geometry, was … highly regarded, and the Greek gods and the divine world had to be conceived as exempt from all time, transitoriness, and change….” (128.)

For Boman, the words “dynamic” and “static” are tentative labels that distinguish between Israelite thinking that is “vigorous, passionate, and sometimes quite explosive” and Greek thinking that is “peaceful, moderate, and harmonious.” In Hebrew, words that we might use for inaction, e.g., sitting, lying and standing, designate a movement that leads to the fixed end-point. (30-31.) “ ‘Dwelling’ for the Hebrews is related to the person who dwells, while for the Greeks and for us it is related to the residence and the household goods.” (31.) Boman finally rejects “the antithesis *static-dynamic*.” “The distinction lies rather in the antithesis between rest and movement.” (55, emphasis in original.)

Static objects at rest fit into forms of knowledge that are different from those that fit actively moving persons. “Ruldolf Bultmann has drawn out an elaborate comparison and contrast between the Greek and Hebrew conceptions of knowledge. …The Greek conceives of the process of knowing as analogous to seeing; that is, he externalizes the object of knowledge, *contemplates* (θεωρει [*theorei*]) it from a distance, and endeavors to ascertain its essential qualities, so as to *grasp* or *master* [] its reality []. It is the thing in itself, as static, that he seeks to grasp, eliminating so far as may be its movements and changes, as being derogatory to its real, permanent essence. … The Hebrew on the other hand conceives knowledge as consisting in *experience* of the object in its relation to the subject. [*Yada*] (Heb. “to know”) implies an immediate awareness of something as affecting oneself, and as such can be used of experiencing such things as sickness (Is. liii 3), or the loss of children (Is. xlvii 8), or divine punishment (Ezek. xxv 14) or inward quietness (Job xx 20)… Thus it is the object in action and in its effects, rather than the thing in itself, that is known; and in knowing there is activity of the subject in relation to the object.” (Dodd, 152, original emphases; transliterations and translation added.)

“[T]he Greeks were organized in a predominantly visual way and the Hebrews in a predominantly auditory way.” (Boman, 206.) Plato, it is said, “is a man of sight, of seeing. His thinking is a thinking with the eyes, proceeding from what is seen…his doctrine of Ideas—is in many ways tied to vision. … Quite as decided in the Old Testament is the emphasis upon the significance of *hearing* and of the *word in its being spoken*.” (201, emphases in original.)

In the literature of ancient Israel, “A seer, *ro’eh*, is a man of God who sees what is hidden from other men, be it runaway domestic animals, hidden sins or future events. …his observation is of an entirely different kind from the Platonic. Greek thinking is clear, logical knowing.” (204.) In contrast to the Greek concept of truth based on “that which is,” the “Hebrew concept of truth is expressed by means of the derivatives of the verb ’*aman*—‘to be steady, faithful’: ’*amen*—‘verily, surely’; ’*omen*—‘faithfulness’; ’*umnam*—‘really’; ’*emeth*—‘constancy, trustworthiness, certainty, fidelity to reported facts, truth’.” (202.)

Summing up corresponding terms, *dabhar* (“word” in Biblical Hebrew) and *logos* (“word” in first century Greek), Boman declares: “these two words teach us what the two people considered primary and essential in mental life: on the one side the dynamic, masterful, energetic— on the other side, the ordered, moderate, thought out, calculated, meaningful, rational." (68.)

"In the Old Testament, [*dabhar adonai* — 'word of the Lord'] is frequently used of God's communications with men, His self-revelation, especially through the prophets, to whom 'the word of the Lord came'. The totality of God's self-revelation is denominated ['*torah*,' or 'Law'], a term which is often parallel or virtually synonymous with [*dabhar adonai*]." (Dodd, 263, transliterations and translations added.)

"For the Hebrew, the decisive reality of the world of experience was the *word*; for the Greek it was the *thing*." (Boman, 206.) Hence, for Hebrews, "Things do not have the immovable fixity and inflexibility that they have for us, but they are changeable and in motion." (49-50.)

"True being for the Hebrews is the 'word', *dabhar*, which comprises all Hebraic realities: word, deed and concrete object. Non-being, nothing (no-thing) is signified correspondingly by 'not-word', *lo-dabhar*. … the lie is the internal decay and destruction of the word…That which is powerless, empty, and vain is a lie: a spring which gives no water lies (Isa. 58.11, *kazabh*)." (56.) "When the Hebrews represent *dabhar* as the great reality of existence, they show their dynamic conception of reality." (184.)

Ideas and impersonal invariants stand as the highest forms of Greek Thought and as ultimate goals of platonic science. Ancient Hebrews had a different conception of the most high.

"Consciousness comprises an entire life and cannot be divided like space … When a song is being sung, its beginning, in our spatial manner of thinking, already belongs to the past and its end still to the future; but, essentially, the song is a living unity which, even after it has been sung to the end and logically belongs to the past, is something present…In a similar way, significant historical events remain indestructible facts in the life of a people. The consequences of the events can be altered in a positive or negative direction by new deeds or failures, but the events themselves can never be altered…" (138.)

"God revealed himself to the Israelites in history and not in Ideas; he revealed himself when he acted and created. His being is not learned through propositions but known in actions. … The people's past, present and future is a continuous whole where everything lives. … Analogous to the life of an individual man, the people's life is experienced as a whole … The nation is a person." (171.)

In ancient Israel, "the word of Jahveh is never a force of nature as in Assyria and Babylonia, but is always a function of a conscious and moral personality." (60.)

b. A beat dwells in muscle-like activity in proposed new technologies.

The following constructions incorporate materials borrowed from Piaget, Nietzsche, ancient Greeks, Clausius, James and modern scientists discussed above, with appropriate modifications. Novel aspects are illuminated by Boman's review of Hebrew Thought and Greek Thought that contrasts movements, individual characters and changes with things, laws and states.

I construct imaginary or metaphysical domains that are populated by operating assemblies of devices. Such imaginary domains resemble computational domains, actual and imaginary, that are constructed by computer scientists, students and hobbyists — but with new and different kinds of devices, signals and operations.

In new proposed technologies – Quad Nets and timing devices – structures embody ***forms of action*** in contrast to components in computer systems that embody digitalized ***forms of state***, such as numbers, arrays, classes and loops. Forms of action are based on ***temporal forms*** while forms of state are based on ***spatial forms***. In each case, forms can be used to control movements. In geometry class, a student follows mental imagery of a spatial form to draw a triangle on the chalkboard; in band practice, the same student follows temporal forms, such as beat and rhythm. Drumming cultures in diverse world communities show that beats and rhythms can be complex and flexible; they often do not fit into forms defined by numbers, arrays, classes and loops.

I suggest that a beat influences movements of a person who follows the beat. The person's movements will slow down if the beat slows down. It would be erroneous, however, to say that the beat determines the person's movements. A person can stop following the beat if the person "wills" or desires to do so. A person can stop following the beat for reasons of mischief or rebellion. A person can stop following the beat for no reason at all or out of boredom.

Tapping feet of musicians are examples of a beat that influences repetitive muscular movements. Whether the connection between ear and foot is innate or socially acquired, facts show widespread habitual activity. The habit is discouraged among classical music performers but is difficult to eliminate. Recently I sat close to a performance by a touring European orchestra that maintained 19th century forms of discipline. The concertmaster had a foot that could not resist tapping, sometimes for several measures at a stretch. He had to silence it repeatedly.

Suppose a jazz band violinist is tapping her foot according to the beat produced by the drummer. I suggest that, although her muscular movements are following the external sound, they have a distinct and separate source within her mind and brain and spine. If the drummer sneezes and omits a few drum strokes, neither the violinist nor her foot need miss a beat. I suggest that the violinist is generating the beat internally in her spine and brain and confirming or modifying that self-generated beat according to the drummer's beat.

I suggest that something like beats drive repetitive movements in actual life, e.g., repetitive movements that are self-perpetuating such as the sucking of the baby that was introduced in § 1. I suggest that baby's sucking and the beat have a common ground in actual life. Actual life is in repetitive movement controlled by the beat as it is in repetitive sucking. Actual life moves a person to dance to the beat for the sake of movement as it moves the baby to suck for the sake of sucking. I suggest that we attach to the beat like the baby attaches to the nipple: because we draw actual life from the beat. Actual life expresses the power to move and we get that power from the beat. We dance together according to the beat — and we get actual life from dancing, from the community and from the unifying beat.

In a newborn baby, actual life depends on beating of the heart that is driven by beating in the brain. The baby attaches to the beating of its mother's heart as a stronger, nurturing source of its own beating. The beating is constant and comes to dwell as an independent presence at the center of the self. As the child grows, the beat develops a capacity to change and explore. A secondary beat appears, a rhythmic accent to the primary beat. The child's growing capacities are based on growth and development of beats and rhythms of beats. Multiple beats and rhythms develop through adaptations in response to demands of actual life. Different persona or personalities with different beats develop for different situations, perhaps with varying demeanors that are sensitive and concerned with other persons, in one situation (e.g., family), or blunt and self-absorbed, in another situation (e.g., work).

The beat is self-perpetuating. The beat generates movements and the beat is in the movements. Movements of actual life come from the beat. Spatial distance is measured according to stepping on the beat. Without movements of actual life, there are no actual objects and there is no basis for sensory objects or mental objects. The beat is the source of rhythms of action and of appetites and impulses that lead to repetitive action. Without repetitive action, there are no fixed memories that can be shaped into forms. Action, sensations, objects, emotions, desires, forms and drives: all are based on the beat embodied in repetitive muscular movements of actual life.

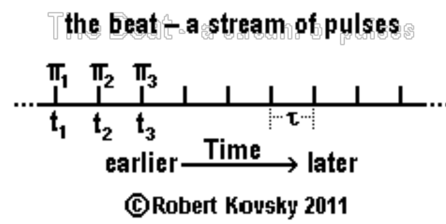
Please compare the foregoing construction with Nietzsche's construction of will to power and Plato's construction of Ideas. Nietzsche's metaphysical construction is based on the importance of desires and drives in our psychology; his construction makes a particular drive, "will to power," into the controlling concept. Platonic Ideas are similarly constructed, but based on invariant visual objects and on geometrical space. My constructions resemble Nietzsche's and Plato's, only mine are based on muscular movements and on "the beat" that leads to models of muscular movements. Similar methods of construction operate on subject matters of desires and drives in the first case, of visual objects in the second case and of muscular movements herein.

One change from the Nietzsche/Plato style is that primal components in my construction – muscular movements – do not assert control over other functions of the personality, such as functions that generate a drive for power or an Idea of Justice. Nietzsche declared the hegemony of will to power based on drives and Plato declared the hegemony of impersonal invariants called Ideas based on visual space. In my constructions, there is no hegemony. Rather, a drive for power and an Idea of Justice can ***compete*** for control of muscular movements, e.g., the muscular movements of a Judge writing a Decision and Decree in a case being litigated. In other situations that better apply to actual life, reflexes and aversions based on physical fear and uncertainty can compete with habits learned through training and with commands of duty. Through shimmering operations that depend on the lifetime character of the person and on exercises of freedom, balances are struck and resolved into courses of action.

Returning to the primal beat: repetitive movements alternate with periods of ***silence***, also called ***rests***. Recall Boman's "rhythmic alternation" discussed above. A spatialization of time, laying time out on a line, makes the period of intervening rest as clear as the period of movement. Music notation includes rests that have exact relationships with the beat, e.g., half measure rests, quarter rests. Viewed with the instrument of spatialized time, movement and rest can have equal status and neither movement nor rest exists without the other. Alternations of movement and rest make up the structure of a beat.

As a chief specification, a beat has a ***tempo***. The tempo is based on a uniform period between pulses in the beat and is described as a certain number of beats per minute ("bpm" in musical parlance). The tempo of a controlling beat must be uniform so that other movements can follow it. Uniformity is a variable and adjustable concept in my constructions: a strict and fixed uniformity amounts to metronomic or mechanical identity; or uniformity may be fluid and variable, *rubato* for musicians. Recordings of Ravel's *Bolero* display some possibilities.

I suggest that such tempi are part of actual life. I suggest that each of us can become aware of the tempo of actual life and can sometimes exercise control over that tempo. To slow down the tempo of actual life, I may say: "I need to think this over." To speed up the tempo, I may say: "Let's get this show on the road."



In the adjacent Figure, "the primal beat" is a stream of pulses. The Figure shows a spatialized passage of time and events that occur during that passage. Equal periods of time have equal spaces in the Figure. As noted above, time has an "arrow." Here, time's arrow flies from earlier to later. The beat occurs while time is passing or flying.

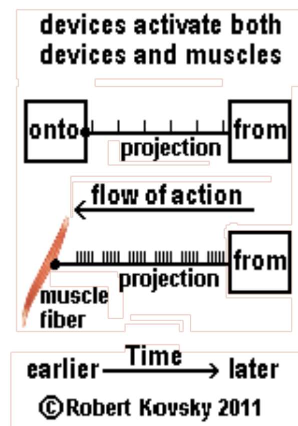
As shown in the Figure, the primal beat is made up of ***action pulses***. Each action pulse – π_j – occurs at a distinct instant t_j. A smaller number in the index (j) refers to an earlier time. There is uniform period – τ – between pulses. A stream of uniform pulses is also called a ***pulse train***.

An action pulse is a movement of "energy." In the Quad Net Model, movements of Virtual Energy involve packets that have variable durations, sizes and shapes. In timing device models, there is only one kind of action pulse with a single uniform size and shape that is sometimes called a "stroke." In this essay, constructions are chiefly based on action pulses (used in timing devices) because of their simplicity. Action pulses in timing devices and Virtual Energy packets in Quad Nets are models of "action potentials" that appear in brain signals.

Movements of energy are presumed to be "instantaneous" in idealized timing device designs. That is, in such designs, a movement of energy occurs in an ***instant***. An instant is a period of time that is much shorter than all other time periods that affect operations of the system. An instant is a period of time so short that doubling it would not affect operations. In practical terms, electrical signals are as the same as instantaneous. In timing device designs, slower biological signals can be modeled by means of delay devices.

In device constructions, parts are hooked together. As shown in hookups in the Figure below, movements of energy occur when action pulses travel from one timing device to another timing device or when action pulses travel from a timing device to a ***muscle fiber device***. In the Figure below, the "flow of action" is from right to left to adapt to spatialized time. Hookups involving assemblies of timing devices are discussed in other publications accessible online; here the focus is on models of muscular activations. Hence, constructions start with muscle fibers..

Timing devices and muscle fibers are connected by ***projections***; each projection is a connection ***from*** a timing device ***onto*** another timing device or onto a muscle fiber device. The projection is part of the "from" device and carries pulses generated by the from device. The projection is connected to an onto device or to a muscle fiber device through a ***junction***; junctions are denoted by dots in the Figure. A projection models the axon of a biological neuron and a junction models a synapse between such an axon and a receptive part of another cell.



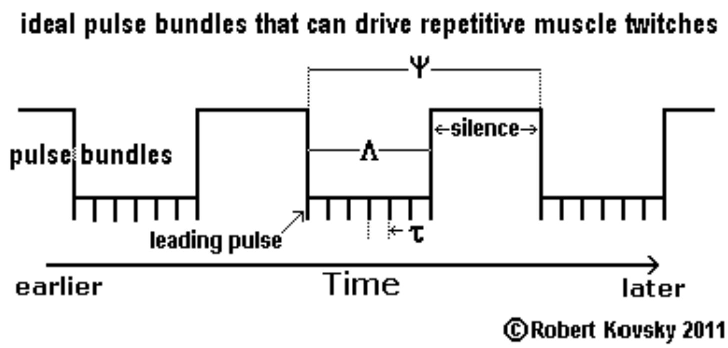
As shown in the adjacent Figure, movements of energy to a muscle fiber occur in the form of ***pulse bundles*** that travel from a timing device — the muscle fiber device responds to pulse bundles by ***twitching***. Repetitive pulse bundles have a repetitive number of uniformly paced pulses in each bundle and a repetitive period of rest between bundles. According to the model, repetitive uniform pulse bundles produce repetitive uniform twitches.

Twitches of muscle fibers are primal activity in my models of actual life. Uniform twitching expresses a primal beat. Each twitch is a forceful contraction of the muscle fiber that can perform physical work. A muscle fiber maintains the contraction for a certain duration of time and then relaxes. In between twitches, the muscle fiber restores its energy reserves.

The "muscle fiber" in my constructions models a "myofiber," the smallest unit of animal muscle. In constructions shown below, muscle fibers are organized in "muscle modules" that function in ways that resemble animal muscles.

From the perspective of models of muscles, the primal beat is carried by a ***stream of pulse bundles***. In such a pulsestream, each bundle is "the same" and consists of a certain number of uniformly-timed pulses. The first pulse in the sequence is called the ***leading pulse***. The leading pulse identifies the arrival of the beat and initiates a twitch.

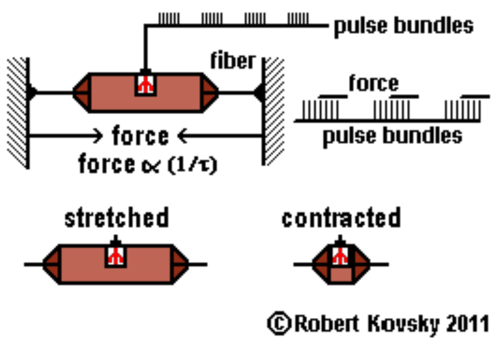
An idealized signal shown in the Figure below is a stream of pulse bundles that is defined by three quantities of time or periods, namely, ψ, Λ and τ. The ***organizational period*** ψ sets the rate of twitching. (I generally use "ψ" to denote the longest period in a system under consideration and "τ" to denote the period of a working pulse train. The ψ period in the Eye for Sharp Contrast is much longer than the ψ that organizes pulse bundles here.) The ***durational period*** Λ controls how long a twitch lasts. The ***signal period*** τ controls the force of a twitch. In a pulsestream of ideal pulse bundles, all three periods are fixed and Λ/τ is an integer. The number of pulses in an ideal bundle is (Λ/τ) +1. There is always at least one pulse in the bundle — the leading pulse that identifies the beat.



In a rudimentary way, a bundle of action pulses resembles a "burst" of action potentials like that observed during operations of biological brains. [In more complex designs, ***bursting devices*** produce signals that more closely approximate biological bursts.] Each bundle or burst drives one twitch of a muscle fiber (constructional), resembling the twitch of a myofiber (biological). Twitching is organized by an invariance principle: repetitive uniform pulse bundles are projected onto a muscle fiber that repetitively and uniformly twitches at the same rate. In connecting to and describing actual life, this means that a muscle is warmed up but not tired. It is the sort of muscular activity of an athlete in training, a data-entry clerk or an assembly-line worker.

The activity of a single muscle fiber being activated by a repetitive beat is shown in the Figure below. The period of twitching is ψ, the period of the beat. There is a delay between the arrival of a leading pulse in a pulse bundle and the start of a twitch. The delay is a specification of the device like the number of ohms is a specification of a resistance. In the Figure, the fixed delay between arrival of a leading pulse and the start of a twitch is equal to 2½ pulse periods (sufficient time for the muscle fiber device to determine and set the force). Similarly, there is fixed relationship between the duration of a pulse bundle, Λ, and the duration of the resulting twitch. In the Figure, the duration of a twitch is arbitrarily set equal to the durational period Λ shortened by one pulse period.

activation of a muscle fiber



Activation of the muscle fiber causes it to produce a contractile force. An unattached fiber becomes shorter. When pulsing ceases or diminishes, the fiber relaxes and stretches out. The initial design is based on activity where actual contraction is prevented; that is, the ends of the fiber are attached to immovable walls. In this situation, the force $\mathcal{F}$ generated by a twitch is $\mathcal{F} = \mathscr{k}/\tau$, where device specification $\mathscr{k}$ is a coefficient that is the same for all τ within a specified range of τ values.

In constructions herein, τ is fixed within each pulse bundle. We can, therefore, use a frequency φ such that $\varphi = 1/\tau$ or $\mathcal{F} = \mathscr{k}\times\varphi$. In words: force increases linearly with pulse frequency in ideal pulse bundles, if the fiber is prevented from contracting.

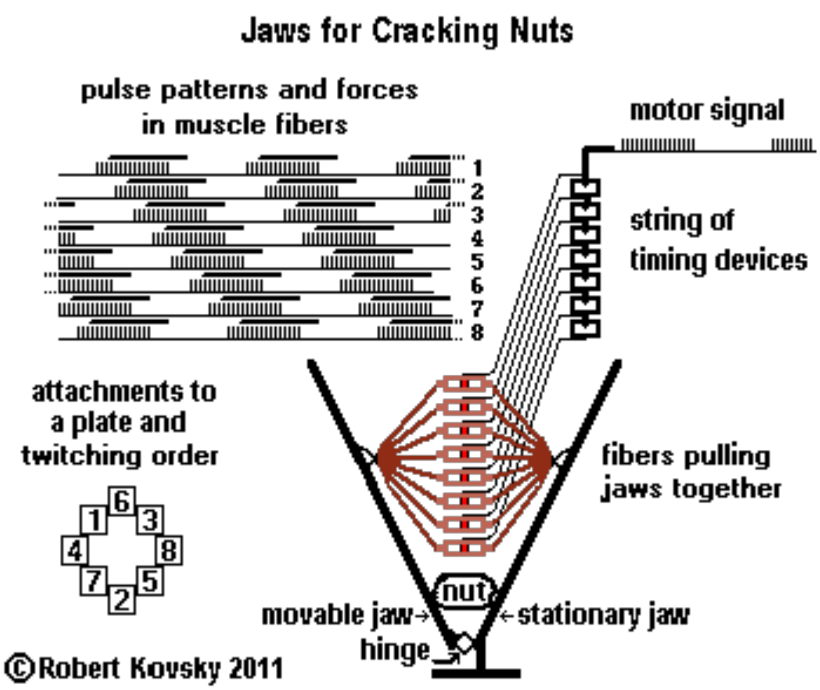
Suppose the fiber is allowed to contract. The question is whether a contracting or contracted fiber generates a force that is different from that of the attached and stretched fiber. To start off, the rule is that there is no difference. A twitching fiber generates the same force whether it is stretched and attached, whether it is contracting or whether it is contracted. Modified rules will be introduced below as part of the construction of A Dogtail for Wagging.

The Figure below shows "Jaws for Cracking Nuts," a timing device design. In the Figure, a nut is compressed between a stationary jaw and a movable jaw. The jaws apply a force that depends on the motor signal, which is a stream of pulse bundles. The string of timing devices distributes the motor signal in ***waves*** to the individual muscle fibers. Each timing device in the string (except for the last such device) drives one muscle fiber and also triggers the next timing device, after a delay. Adjustable motor signals and delays within the string control the activity.

Each muscle fiber rhythmically contracts and relaxes. The goals of the design are to convert such rhythmic activity of muscle fibers into steady forces produced by the jaws and then to control the forces. The goals are achieved, in an approximate way, by symmetrical attachments of muscle fibers to the jaws at ***plates***, which crudely model the insertion of a tendon into a bone.

(Compare to P. Lui, *et. al.,* Biology and augmentation of tendon-bone insertion repair (2010) http://www.josr-online.com/content/5/1/59.)

Numbered attachments to the plate refer to the sequential order of fiber activations. Timings are adjusted so that 1 follows 8 like 4 follows 3. During operations, three or more sequentially numbered attachments pull together at any instant; pulls are all equal and the sequence continually shifts around the plate in a step-wise fashion. I suggest that forces pulling the jaws together will be steady, more or less, and tolerating a certain amount of "wobbling."



In sum, Jaws for Cracking Nuts should achieve design goals of converting twitches of muscle fibers into steady and controllable muscle-like forces. The design operates with a signal that carries a steady repetitive beat in the motor signal made up of bundles of action pulses delivered to a bundle of muscle fibers. The beat is a temporal form that controls pulls of the jaws.

A sub-system like the Jaws can maintain a fixed or steadying force while other sub-systems are actively moving. Co-existence and coordination of steady parts and moving parts is a general design goal. In actual life, steadying forces are exerted by fingers holding a nearly-full coffee cup while the rest of the body is moving from one room to another. Some animals transport eggs in their mouths, a delicate task requiring jaws that remain steady while other parts of the body are moving. Such steadiness is an adaptation of muscular activity to invariants, namely, the actual object being held and the direction of gravitational force. An organism that stands upright and holds one object steady with certain muscles while it moves its own body and other bodies with oth er muscles can attempt to control events in its environment. Such capacities are important in actual life.

c. "A Dogtail for Wagging" is a timing device design for production of classes of muscle-like movements, including positioning movements, kicking movements and wagging movements controlled by a beat.

Muscle-like movements are goals of constructions – yet, the foregoing design of Jaws for Cracking Nuts does not involve movement. Although the forces on a nut can be varied, there is no suggestion that the forces move anything. Using terms from "classical mechanics" (discussed below), the problem is one of "statics" rather than "dynamics." Movement would occur if a nut were to be cracked. In such an event, forces between jaws must be suddenly reduced so that, after collapse of a nut, the jaws do not damage each other. Advanced designs would use saccadic or jumpy control to prevent such damage: a sudden drop in pressure sensed at the jaws causes a sudden reduction in the size of pulse bundles to jaw muscle fibers.

An Eye for Sharp Contrast does involve muscle-like movements. Each ψ cycle, forces produced by muscle fibers squeezing the Lens become either stronger or weaker, through an incremental step. As a result, the Lens changes shape and becomes either one step stronger or one step weaker in focusing power. Step-wise changes in muscle-like forces adjust the focus of the Eye so as to find the sharpest possible image of an external object. Such cyclical stepping resembles a quasi-static process in thermodynamics: it is slow and it is limited in range and resolution.

A Dogtail for Wagging, proposed herein, is a more advanced timing device design for production of multiple classes of muscle-like movements, namely, quasi-static or positioning movements, continuous movements (wagging) and jumpy or saccadic movements. The construction path goes through stages. The initial design can maintain a class of static positions but is not suitable for movements or for performance of work. Development leads to a Dogtail design that also produces wagging movements and jumpy or kicking movements but that does not perform significant work.

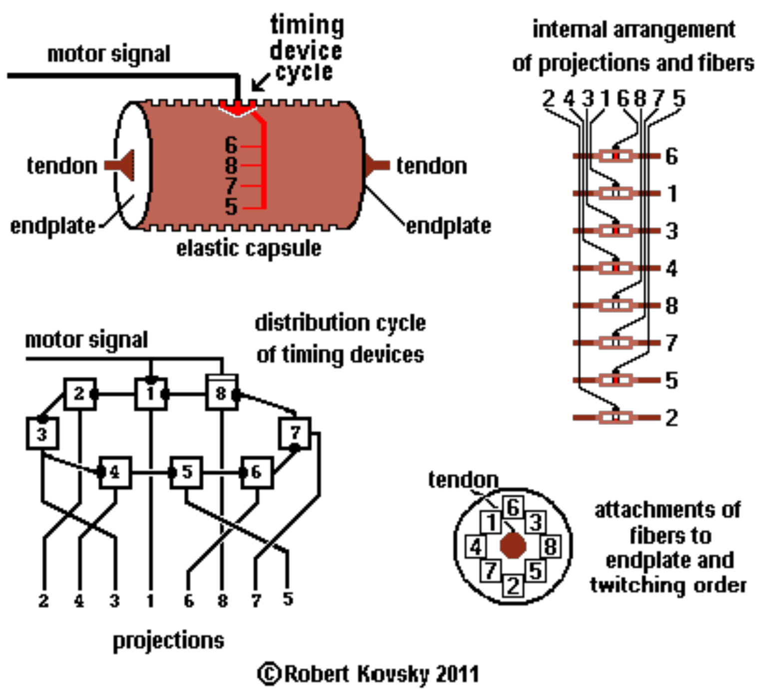
Further analysis shows that the methods of classical mechanics can apply to positioning movements but not to the other classes of movements. The methods of classical mechanics disregard systems that incorporate energy dissipation and/or that have "non-holonomic constraints." The shortfalls would be even more significant for a device design that performs actual work, e.g., A Fishtail for Propulsion. Overall, the constructions show how forms of physics fail to describe muscular movements of organisms that have actual life.

The Figure on the next page shows a muscle module for the Dogtail design. The module is developed from the design of muscle fibers, as used in Jaws for Cracking Nuts, along with some major modifications.

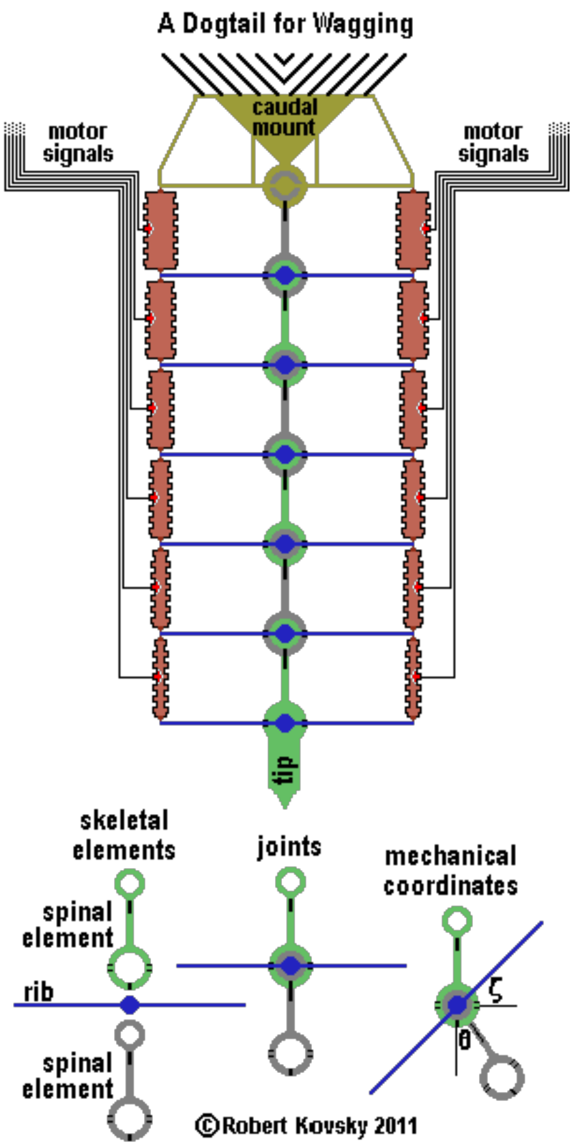
The eight muscle fibers that pull the Jaws are enclosed within an ***elastic capsule***, with an internal arrangement that substitutes for the plate in the jaws design. The encapsulated unit becomes a freestanding ***module*** connected by ***tendons*** to other components. Also, the distributive hookup of timing devices is closed into a ***cycle*** within which a pulse bundle circulates, repetitively activating fibers inside the capsule. (For actual operations, the number of timing devices in the cycle must exceed ψ/τ; interstitial devices can be used but are omitted in the Figure.)

The cycle of timing devices is incorporated as part of the muscle module capsule, a feature that contrasts with some biological organisms, where neurons and muscles are separated. Simpler images are the immediate benefit. I suggest that, in biological organisms, similar functions are performed by neurons located in spinal vertebra, close to muscles and distant from brains. During device operations, a new pulse bundle carried on the motor signal line interrupts and replaces a pulse bundle circulating within the timing device cycle. The special "gate normally open" timing device at position 8 in the cycle performs interruptions.

A Dogtail for Wagging – muscle module



In sum, so long as no motor signal is received, the muscle module produces a muscle-like force that is approximately steady. In addition, changing motor signals can produce changes in muscle-like forces. In the idealized design, the force produced by the muscle module follows the input motor signal in math-like ways that are predictable in timing and intensity and that do not depend on the order of changes. In such a design, muscular force can be changed in incremental steps, in a continuous ramping way or in jumps, according to motor signals selected by the operator.

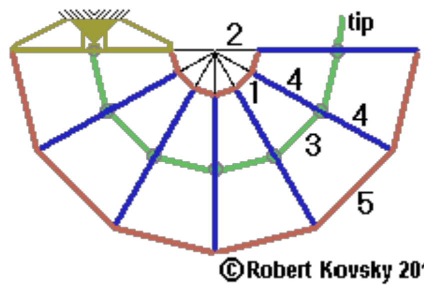


The design of A Dogtail for Wagging is shown in the adjacent Figure. Twelve muscle modules are attached in opposing pairs to a skeleton that has seven joint units. Each muscle module is controlled by a motor signal carried on a line from a timing device. The Dogtail is affixed to an immovable ***caudal mount*** at the first or caudal joint. The ***tip*** at the opposite or distal end is free-ranging.

The Figure also shows rigid skeletal elements: ***spinal elements*** and ***ribs***. Two spinal elements and a rib element make up a joint unit that has two joints. Within a joint unit, the smaller circular end of a spinal element (the gray spinal element in the lower Figure) denotes a thin cylindrical wall standing perpendicular to the page, with ball bearing races on both sides of the wall, each race facing a matching race in another element with a matching wall. Each joint unit has two separate joints that operate through ball bearings and that move independently. The two joints have two mechanical coordinates, θ and ζ, which track angular positions from joint to joint. (The design moves in two dimensions; the system needs three dimensions.)

Movements of the Dogtail take place within a ***range of motion***. An extreme position marks the limit of the Dogtail's range of motion, as shown in a simplified form in the Figure below. A mirror image of the Figure would identify the limit of the range of motion on the other side.

Each pie-piece segment in the Figure includes legs in three concentric regular dodecagons (12-sided polygons), or halves thereof.



Sizes of components are based on numbers next to elements in the adjacent Figure. Each spinal element has a length of 3 units. Each rib has a length of 8 units, 4 units on each side. The length of a fully contracted muscle module is 1 unit; the length of a fully stretched muscle module is 5 units. The number 2 refers to a line segment that is part of three similar triangles.

Each mechanical coordinate θ ranges from –30° to +30°; each mechanical coordinate ζ ranges from –15° to +15°. A statement of 6 θ's and 6 ζ's specifies the position of the Dogtail within its range of motion. Values of 12 muscle lengths can be derived from a statement of values of 12 mechanical coordinates and vice versa.

Define ***centerpoint*** activity of the Dogtail as symmetrical, vertical positioning of the skeleton, as shown on the preceding page. Such centerpoint activity is maintained by symmetrical pulse bundles cycling in muscle modules. Nothing moves during centerpoint activity; it is like zero in arithmetic. Centerpoint activity is maintained by symmetrical motor streams of pulses that can vary from low volume to high volume. When pulse streams have a low volume, centerpoint positioning is "loose" in contrast to "taut" positioning at a high volumes. Determinations of "loose" or "taut" would be based on responses to external test forces.

Now suppose we introduce movement away from the centerpoint by increasing the duration Λ of right side bundles in the motor signals so as to cause the number of pulses in right side bundles to increase by one, leading to an increase in contractile right side forces. Left side bundles are not changed. The Dogtail bends towards the right. As set forth above in the definition of muscle fiber, the force generated by a muscle fiber is independent of the length of the fiber. Hence, all forces remain at constant values as the Dogtail moves. Therefore, the movement will continue until the Dogtail reaches the limit of its range of motion.

Such operations are not useful. Any change in signals initiates ongoing movement that runs to the end of the range. It might be possible to control movements by applying little jerks, pausing between jerks by returning to symmetrical signals – but such little, jerky movements would not resemble large movements of actual life such as wagging.

We thus return to the question of force versus length of muscle fibers noted above. I suggest two ways to modify the force produced by a muscle module according to its length and to thus make useful operations possible. One way uses "elastic modeling," which fits forms of platonic science. The other way uses "dissipation modeling." Comparison shows that dissipation modeling is more like what happens in actual life. On the other hand, muscles do exhibit some elasticity. Models could also combine elastic modeling and dissipation modeling. Models can attribute elasticity or dissipation to muscle fibers or to the capsule of the muscle module. The following constructions explore some of these possibilities.

Elastic and dissipation models both start with the force relation introduced above in connection with activation of a muscle fiber, namely, $\mathcal{F} = \mathcal{k}/\tau$ or $\mathcal{F} = \mathcal{k}\times\varphi$ for ideal pulse bundles with uniform ψ, τ and Λ. Principles of symmetry and supposed steadiness support generalization of the force relation so that it also describes a steady force produced by a muscle module; let $F=k\varphi$ represent such a steady force. In both force relations, within a range of operation, a proportional change in frequency causes a proportional change in force – hence both relations are linear. The frequency φ is the same in the two force relations but the force generated by a muscle fiber ($\mathcal{F}$) is different from the force generated by a muscle module (F). $\mathcal{F}$ is twitching while F is steady, with some wobbling of F that may depend on operations. The coefficients $\mathcal{k}$ and k are also different.

Let L denote the length of the elastic capsule, a variable quantity that depends on the motor signal. Let L_0 be the minimal length, 1 unit in the above design. Similarly, let L_1 be the maximal length, 5 units in the design. L ranges between L_0 and L_1.

For elastic modeling, modify the force relation for the muscle module to become:
$F = k\varphi + \hat{\jmath}(L - L_0)$ where $\hat{\jmath}$ is a linear coefficient with dimensions mass/sec^2.

This model applies to a device where an elastic capsule adds an elastic contractile force to the contractile force produced by pulse bundles. The elastic contractile force becomes greater when the muscle module is stretched, following Hooke's Law for an elastic spring. In other words, a stretched elastic capsule pulls endplates together with a force that depends on the extent of the stretch. Using a physics description, such a muscle module produces two parallel forces, one force like that from a rubber band plus an adjustable force that is controlled by motor signals.

Elastic modeling appears to partially resolve the problem noted above in the original model. Suppose the Dogtail is in a vertical position with symmetrical pulse bundles cycling in opposing muscle modules on right and left sides. Now, as before, suppose that changes are made in right side motor signals that cause a slight increase in right side forces. The Dogtail bends towards the right. As it bends towards the right, right-side muscle modules contract, reducing their lengths, and left-side muscle modules stretch, increasing their lengths. Using the new force relation, and as a result of changing positions, right-side modules generate lesser forces and left-side modules generate greater forces. As movement goes forward, the additional forces balance the change in forces resulting from the change in τ and the net force shrinks to zero. If things are done slowly and properly managed, the Dogtail eases into a new steady position. It would appear that the Dogtail can be put into a large class of positions that includes the two extreme limit-point positions and a continuous class of diverse shapes between the two extreme positions.

Formally, a system of relations connects each specific position defined in terms of a set of lengths of muscle modules (or, equivalently, a set of θ's and ζ's) with a set of cycling bundles, or, equivalently, motor signals. Fix the motor signals and get a specific position. Adjustment of motor signals results in adjustment of position.

Dissipation modeling is more abstract. Instead of an elastic force added when the capsule is stretched, thus increasing the force strength of a stretched capsule, dissipation modeling employs a reduction of strength in a contracted fiber. Strength or energy is simply wasted or dissipated. In symbols, $F = k\varphi - j(L_1 - L)$. In brief, the model suggests that a contracted fiber is weaker than a stretched fiber because of differential dissipation processes. Perhaps energy is required to maintain the contraction and cannot be used for muscle-like movements of massive bodies.

Reiterate the previous procedure to investigate dissipation modeling. Suppose that the Dogtail is initially engaged in centerpoint activity and that changes thereafter occur in motor signals which increase contractile forces on the right side. The Dogtail bends to the right. As it does so, contracting right-side fibers and modules lose strength and stretching left-side fibers and modules gain strength. (The capsule produces no force.) These changes reduce the forces that cause movement. When force changes resulting from greater dissipation are equal to force changes resulting from motor signals, movement of the system ceases.

Obviously, a single mathematical form of force relation is common to the two models. It is a linear relation for F with two variables, the same φ and a length difference that is similar in the two models. There are, however, significant differences between the two models. In considering actual activity of the models, storage of energy in the elastic capsule presents operational problems that are reflected in a phrase in the elastic model description above: "If things are done slowly and properly managed…" Implicitly, if things are done quickly and are not properly managed, movements of a Dogtail will be influenced by conserved elastic energy, e.g., "whipping" back and forth and/or "quivering" around a fixed position.

For elastic modeling to work to balance opposing muscle modules, the difference between elastic forces generated by opposing capsules must be sufficient to balance the force difference produced by maximal and minimal flows of pulse bundles to the opposing muscle modules. Elastic forces are produced by stored energy. A large force difference requires large amounts of energy storage. Energy storage is like that found in elastic springs. If motor signals should suddenly decline on both sides, stored energy might "spring" into action and start quivering. An elastic system will contain large quantities of stored energy that can interfere with operations.

The dissipation model does not present such a problem. Energy is always being dissipated. If one module were to approach minimal dissipation, the opposing module would have maximal dissipation. I suggest that there is always a point in the dissipative model where things are in balance and that the system ends up at that point. In other words, with fixed motor signals, a Dogtail based on the dissipation model should "settle down" or relax into a fixed position.

Such considerations become even more important in wagging and kicking movements where stored energy adds a complicating factor. For example, a kick using elastic modeling will be followed by a kick in the opposite direction and back again unless a corrective force is applied. A kick loses energy with dissipation modeling and quickly comes to rest.

Dissipation designs turn on wastage of energy rather than on storage of energy. Storage of energy requires adherence to a conservation principle while wastage can be based on a variety of principles. In other words, dissipation designs offer greater scope for variation. E.g., it is possible to use a nonlinear dissipation form $F = k\varphi - j'(L_1 - L)^2$ or to combine elastic and dissipation modeling, e.g., $F = k\varphi + \hat{\jmath}(L - L_0) - j'(L_1 - L)^2$.

For purposes here, I use linear dissipation modeling $F = k\varphi - j(L_1 - L)$. It appears that the dissipation model can establish a set of relationships between fixed shapes of the Dogtail and fixed patterns of pulse bundles maintained in cycles in muscle modules. Each fixed pattern of cycling bundles establishes a specific fixed shape into which the Dogtail relaxes. Each fixed shape is defined by a set of θ's and ζ's or, alternatively, lengths of muscle modules.

The Dogtail is designed to produce three classes of movements: (1) positioning movements, discussed above (2) wagging movements and (3) kicking movements. These resemble three classes of muscular movements produced by college athletes: "(1) slow tension movements, (2) rapid tension movements, and (3) rapid ballistic movements." (Cooper *et. al.*, *Kinesiology*, 113.) The following construction connects proposed movements of the Dogtail to sports movements of actual life.

Positioning movements are the easiest because they are based on fixed shapes. Each fixed position is associated with a class of sets of cycling pulse bundles. As in the case of centerpoint activity discussed above, many different cycling pulse bundle patterns can maintain a single particular fixed position.

Suppose the Dogtail is in a specific position maintained by a particular pattern of cycling pulse bundles, e.g., in centerpoint position. Suppose we want the Dogtail to move by positioning movements to a new fixed shape. The new shape will be maintained by any of a new class of sets of cycling pulse bundles. It would appear to be possible to move the Dogtail towards the desired shape through incremental changes in motor signals, with a trajectory of motor signal changes that is aimed at arriving at a pattern in the desired end-class of cycling pulse bundles that will maintain the desired shape. The size of each incremental change is small enough so that each movement is small, predictable and controllable. Summing up, positioning movements are predictable and controllable incremental changes in shape resulting from incremental changes in step-wise patterns of cycling pulse bundles.

Positioning movements can be described using terms similar to those used by kinesiologists to describe certain sports movements:

"**Slow tension movements**. Slow movements of body parts … is indicated by moderate to strong cocontraction of antagonists [opposing muscles]. The cocontraction serves to fix the joints involved in the action and to aid in accurate positioning of the body part…In the slow, controlled forms of movement, the antagonistic muscles are continuously contracted against each other, giving rise to tension. Tremors occur when antagonistic muscles are in contraction and balanced against each other in fixation.

"Voluntary movement has been observed by Travis and Hunter to be a continuation of a tremor without interruption of the tremor rhythm. The elementary unit of a slow, controlled movement is the *tremor*. If a short movement is attempted, its amplitude is determined by that of the tremor. Ability to make movements more and more minute is limited not by sensory methods of control but by the fundamental tremor element…

"Slow, controlled movements result from a slight increase in the algebraic sum of the number of the muscle fibers contracting the positive muscle as against the number of fibers contracting in the antagonist muscle group. The limb moves in the direction of the group exerting the stronger pull, and tension of the two groups of antagonistic muscles is continually readjusted." (*Id*., 113, emphasis in original.)

In the kinesiologists' description of slow tension movements, there is a sequence of short movements from position to position, movements that are called "tremors," and the cumulative result is "slow, controlled movement." The tremors occur rhythmically and appear to have a more or less definite amplitude. The description is congruent with positioning movements of the Dogtail where patterns of pulse bundles in motor signals are periodically and incrementally changed.

The second class of movements of the Dogtail is conceived as the polar opposite of positioning movements, namely, kicking movements. Kicking movements incorporate the most sudden and forceful action that the system can produce.

An extreme kicking movement starts with the end-of-range position shown above. The end-of-range position is maintained by the most highly activated pulse bundles cycling in the contracted side and a very low level of activation in the stretched side. There is a large amount of dissipation or wastage on the highly activated and contracted side and very little dissipation on the stretched side.

Now, as quickly as possible, reverse the character of the cycling pulse bundles by introducing new motor signals so that the most highly activated signal is delivered to the stretched side while the lowest level signal goes to the contracted side. Suppose that muscle fibers in a module respond so quickly to such reversals that changes in forces are completed within a single cycle of operations, even before substantial actual movement, which takes some time to start because of inertial mass. The most highly activated signal drives a stretched muscle module where there is minimal dissipation and the resulting force is higher than the highest force possible on the contracted side. Meanwhile, the effect of the lowest level signal going into the contracted side is reduced even further by high dissipation and the module produces scant opposition to sudden forces produced on the other side. The result should be a kick-like movement:

"**Rapid ballistic movements**. A ballistic movement, begun by a rapid initial contraction of the prime movers, proceeds relatively unhindered by antagonistic contraction… In comparison with the activity of the prime movers, the tension in the antagonists is slight during the ballistic type of movement." (113)

The third class of Dogtail movements, wagging movements, is a distinct class. In contrast to both positioning movements and kicking movements, wagging has no moment of rest; and moving body parts are always carrying momentum. Detailed consideration of momentum would require defining masses of body parts. Such detailed considerations are not practical for purposes here; but I suggest that the Dogtail design could produce a class of controllable wagging movements.

It appears that wagging fits into Cooper et. al.'s third class of movements (113): "**Rapid tension movements.** A movement in which tension is present in all the opposing muscle groups throughout the motion may be considered a movement of translation superimposed on fixation."

I suggest that a "movement of translation superimposed on fixation" starts the wagging movement and imparts momentum to body parts. Cooper et. al. also consider the termination of movements. In the ballistic movement of a golf swing, "movement is terminated by co-contraction of the opposing muscles and the loss of momentum. If the movement is arrested by a strong contraction of the antagonistic group and as a result moves in the opposite direction, the movement is said to be *oscillatory*." (*Id*., 113-114, emphasis in original.) I suggest that wagging movement is maintained as an oscillatory movement.

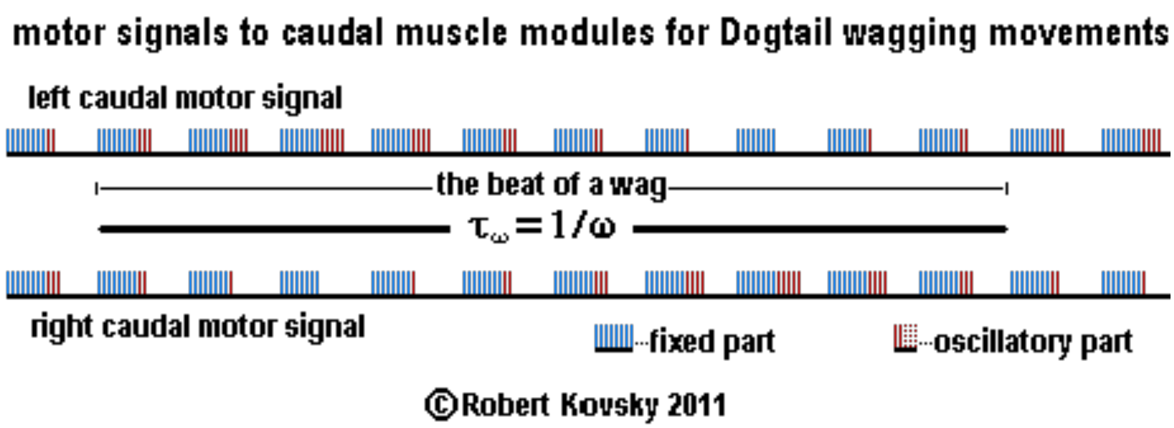
The kinesiologists' description of sports movements suggests a path for construction of wagging movements of the Dogtail. Begin with centerpoint fixation that is maintained by symmetric opposing patterns of pulse bundles that drive muscle modules. Then, superimpose on such fixation a movement of translation. The movement of translation is an ***asymmetry***. One side of the Dogtail is pulled by stronger contractile forces than the other side and the system bends to that side. Asymmetric translation starts the movement.

To maintain such movement in the Dogtail, cyclical adjustments in patterns of pulse bundles produce an oscillation. A wagging movement starts in the lowest or caudal joint of the Dogtail by a sustained pull to one side. For purposes here, the focus is on the first or caudal joint as the prime mover. Signals to later, more distal joints are adjusted for smooth operations after caudal movements are performed. (Sometimes, a dog wags only the caudal joint and holds the rest of the tail stiff.)

Now suppose that muscle modules actually set the Dogtail into movement. It's not just standing in a relaxed position (after a positioning movement) or standing in a tense position (getting ready for a kick). It is actually moving.

Movements are caused by contracting modules on the "agonist" side. As the Dogtail moves, muscle modules on the "antagonistic" side are stretched and resistive forces grow stronger. As the cycle continues and pulse bundle patterns on the antagonistic side become stronger, their increasing strength not only slows down movement, but goes on to reverse momentum. After reversal proceeds and the Dogtail is moving in the new direction, the asymmetry in the motor signals switches again and mirror image activity takes place. Soon it is time for another reversal. If a Dogtail has many joints, distal parts far from the caudal joint may still be moving to the right while the caudal joint has begun moving to the left. The character of such a movement through the tail is wave-like. Such wave-like and oscillatory movements embody a beat with a tempo that is partially controllable.

The Figure below shows motor signals to caudal muscle modules that would maintain wagging. The frequency of the beat of constant wagging is denoted by ω; let $\tau_\omega = 1/\omega$ denote the period or beat of a wag.



In sum, the motor signal for Dogtail wagging is a repetitive cycle where the number of pulses in pulse bundles goes up and down in a smooth way. One component of the signal is constituted by symmetric pulse bundles that are constant and this component fixes the joints; and, superimposed on such fixation signal, there is an asymmetric oscillatory signal. The beat ω organizes the oscillatory pulse patterns.

d. Forms of platonic science do not connect to, control or describe kicking or wagging movements of A Dogtail for Wagging.

The Dogtail construction is a proposed mechanical system that can be investigated by mathematical methods of classical mechanics stated in Goldstein, *Classical Mechanics* (1950).

An important distinction in classical mechanics is that between ***statics*** and ***dynamics.*** Statics examines the arrangement of mechanical forces in a system where components are immobile, asking, e.g., whether a member in a roof truss can bear an expected stress. Dynamics investigates activities of systems with parts that are moving with respect to each other, "moving parts" in common parlance.

On one hand, dynamics is the more general approach and statics is a special case, so statics appears to be less powerful. But, on the other hand, static systems are easier to investigate and results based on static systems have forms that are conceptually and computationally convenient. Investigators asked: is it possible to employ the beneficial results obtained through statics investigations in investigations into dynamics? The answer is: yes, but only for a restricted class of cases. That restricted class of cases makes up the bulk and conceptual substance of modern physics. Activities of actual life, however, are not included within the restricted class of cases. My impression is that some physicists do not consider such restrictions when they declare the universal application of their science.

Classical mechanics posits a system with defined parts that move with respect to each other. The system is constructed in an imaginary domain governed by "Laws of Physics" that operate like rules in a game. Parts in such a system can consist of particles, rigid bodies or deformable bodies subject to force rules such as force rules for muscle modules set forth above. Parts in such a system are subject both to forces applied from outside the system and also to forces from other parts of the system, called "forces of constraint." (Goldstein at p. 10.)

Goldstein's construction begins with a restriction that such a system be at overall rest with respect to the observer. (5.) Next: "Suppose the system is in equilibrium, i.e., the total force of each particle vanishes…" (14.) That is, applied forces and forces of constraints sum to zero for each and every particle in the system. As in classical thermodynamics discussed above, the mechanics construction starts with equilibrium. A system with an underlying static character is established both as a whole and in each of its parts. This is the first restriction on systems being considered.

The second restriction uses the concept of "virtual work" that would be performed if components in a static structure were allowed to move just a tiny bit under the influence of applied forces and forces of constraints. Goldstein distinguishes between virtual work performed in response to applied forces and virtual work performed in response to forces of constraint. "We now restrict ourselves to systems for which the *virtual work of the forces of constraint is zero*. We have seen that this condition holds for rigid bodies and it is valid for a large number of other constraints. … This is no longer true if frictional forces are present, and we must exclude such systems from our formulation. The restriction is not unduly hampering, since the friction is essentially a macroscopic phenomenon." (*Id*., 15, emphasis in original.)

With such restrictions in place, "we use a device first thought of by James Bernoulli, and developed by D'Alambert. …dynamics reduces to statics." (15.) The resulting formulation is called D'Alambert's principle. Unfortunately: "It is still not in a useful form to furnish equations of motion for the system. We must now transform the principle into an expression…" The transformation applies "for holonomic constraints," the third restriction. (16.)

The third restriction, holonomic constraints, requires that constraints fit into a certain form that "can be expressed as equations connecting the coordinates of the particles (and the time)." (11.) "An oft-quoted example of a nonholonomic constraint is that of an object rolling on a rough surface without slipping … the 'rolling' condition is not expressible as an equation between the coordinates...Rather, it is a condition on the *velocities* (i.e., the point of contact is stationary), a differential condition which can be given in an integrated form only *after* the problem is solved." (12-13, emphases in original.) "If non-holonomic constraints are present then special means must be taken to include these constraints in the equations of motion." (156.)

The foregoing restrictions lead to Lagrange's equations. (15-18.) Lagrange's equations connect spatial homogeneity to conservation of momentum; and, likewise, they connect spatial isotropy to angular momentum. The discussion in Goldstein is titled "Conservation theorems and symmetry properties." (47-49.) Lagrange's equations are also the basis for Hamilton's equations of motion. (215-218.) Hamilton's equations of motion, in turn, are the basis for statistical mechanics. (Gibbs 3-5.)

In sum, applications of statistical mechanics are limited to a highly restricted class of systems.

Operations of the Dogtail can be analyzed with respect to the restricted class of systems that is investigated by classical mechanics and statistical mechanics. The class of positioning movements appears to come closest to movements that are within the scope of the restrictions. Each fixed position appears to be in equilibrium; equilibrium is clearly shown in the case of elastic modeling, which is formally equivalent to dissipation modeling. A suitable definition of virtual work could lead to zero virtual work performed by constraints, as required by the mechanics construction set forth in Goldstein.

It also appears to be possible to adapt the constraints in positioning movements to the holonomic form. Forces of constraint in the Dogtail [$F = k\varphi - j(L_1 - L)$] depend on cycling pulse bundles and on lengths of muscle modules. Given specific values for the mechanical coordinates of a fixed Dogtail shape, the θ's and the ζ's, it is possible to calculate the lengths of muscle modules. For each fixed shape, that is for each set of mechanical coordinates and module lengths, there is a class of cycling pulse bundles that maintains the shape. A cycling pulse bundle is equivalent to a repeating motor signal. In other words, many different repeating motor signals will lead to a single fixed shape. However, each repeating motor signal will lead to only a single fixed shape and the total class of repeating motor signals appears to fall apart into disjoint sub-classes with each sub-class leading to a single fixed shape. Therefore, it appears that identification of the sub-class of repeating motor signals serves as the equivalent of identification of the forces of constraint. Classes of repeating motor signals and shapes thus serve as indices of each other and can be put into correspondences. The correspondences guide the movements.

Hence, the class of positioning movements appears to be within the scope of the classical mechanics construction.

However, the same process of reasoning shows that neither wagging movements nor kicking movements comes within the scope of the mechanics construction. That is, in sum and overall, the classical mechanics construction fails to describe the general class of movements of the Dogtail.

In other words, the class of actual motor signals is much richer and more powerful than a formal class of signals that would be constructed from constant motor signals that put the Dogtail into fixed positions. Actual motor signals include those that wag and kick the Dogtail, along with other additional actual movements. Actual motor signals interact with momentum of Dogtail body parts in ways that are difficult to imagine.

The failures appear clearly when actual wagging operations are compared to Goldstein's restrictions. Wagging operations require both cyclical driving forces and cyclical dissipative forces but the forces use different principles and any combination is complicated.

Activities of actual life are outside restrictions of the Goldstein analysis. Unless restrained, animals will not remain at overall rest with respect to an observer. The muscular movements of animals, like wagging movements of the Dogtail, are not based in equilibrium. At all times during wagging movements, parts of the Dogtail carry momentum and the momentum of each part is increasing or decreasing. Work is continuously being generated by the Dogtail; and energy is continuously being dissipated. Similar processes appear to operate in animals.

A further restriction requires that "the virtual work of the forces of constraint is zero." Here, forces of constraint are produced by muscle modules. During wagging movements, modules are actually working, moving inertial mass, working against each other and working against momentum. Such actual work is very different from zero. For example, it has a specific beat.

The final restriction is based on holonomic constraints. Holonomic constraints are stated in terms of positions and not in terms of velocities or other movement-based quantities. During steady wagging, the relationship between motor signals and wagging movements is not based on positions of anatomical elements but, rather, on timing intervals that define pulse bundles and the beat for wagging, ω. The researcher slowly changes ω to change wagging movements. In terms of system control, such motor signals are ***independent coordinates***. Motor signals are independent of the position or movement of the Dogtail and motor signals control steady wagging movements of the Dogtail. Holonomic constraints do not fit the Dogtail.

Sudden changes in Dogtail wagging would be even more troublesome. Interactions between muscle spasms and moving body parts can be complex, even "turbulent," as shown by epileptic seizures. Spasmodic movements do not appear to be subject to the Goldstein analysis.

Suppose the Dogtail were to be developed into A Fishtail for Propulsion. The muscular design of a biological fishtail is entirely different from the design of the Dogtail. The reason is simple. A biological fishtail must perform a lot more work than the Dogtail performs or even than a biological dogtail performs.

Accordingly, a biological fishtail has a lot more muscle than would be possible with a dogtail design. Muscles in fishtails do not connect skeletal members as in the Dogtail; rather, muscles are attached to the skin and connect skin to vertebra. Fish muscles take the form of ***myomeres***, which come in zig-zag layers of solid blocs of muscle, structures that can be dissected at the dinner table. They hold some conserved (elastic) energy, which causes fishtails to flop.

Suppose A Fishtail for Propulsion were to be designed to fit such facts. Were such a Fishtail to be actually immersed in water, the mismatch of its activities with forms of classical mechanics would be even more pronounced than in the case of the Dogtail. Any actual movement of the Fishtail would require work to move water and such work would be greater than work exerted to move the Fishtail itself or work wasted in dissipation. The chief design goal would be to move water efficiently. Constraints would depend on the physical properties of water, including turbulence. Turbulence, actual workloads and dissipations of operating fishtails are all outside the scope of platonic physics. In actual life, fish use their tails not only for steady swimming but also for kick-and-glide movements and braking and backing maneuvers. (Flammang & Lauder.)

Modern physicists are apparently satisfied with restrictions that exclude muscular movements of actual life from the scope of their investigations.

"The physicist today is primarily interested in atomic phenomena. On this scale all objects, both in and out of the system consist alike of molecules, atoms or smaller particles, exerting definite forces, and the notion of constraint becomes artificial and rarely appears. … constraints are always holonomic and fit smoothly into the framework of the theory." (Goldstein, 14.)

e. Classes of muscle-like movements of the Dogtail correspond to activations that generate temporal forms in new technologies. Constructions lead to episodic balancing forms, where symmetry between possible outcomes is established at the start; then symmetry changes to asymmetry as two or more possible outcomes change into one actual outcome. Proposed Quad Net devices embody episodic balancing forms in transformational processes of Shimmering Sensitivity.

Constructions that conclude the essay are more far-ranging and speculative than in the Dogtail construction. This section first presents a muscle-based psychology of freedom and then connects it to proposed new technologies. Non-technical constructions in the final section investigates exercises of freedom that occur during sports competitions and judicial proceedings.

Development commences with the three classes of muscle-like Dogtail movements:
(1) positioning movements, (2) wagging movements and (3) kicking movements.

Each class of Dogtail movements is associated with a distinct corresponding ***activation***:
(1) quasi-static activations, (2) continuous activations and (3) saccadic activations. Quasi-static activations produce positioning movements; continuous activations produce wagging movements; and saccadic activations produce kicking or jumpy movements.

There is a fourth level of activation, ***shimmering activations***. Saccadic activations generate jumpy signals while more highly developed shimmering activations generate jumpy signals with multiple choices. For example, saccadic activations are used to model saccadic eye movements. In anticipated designs, a saccadic activation models the "vestibular-optical reflex" or VOR. The VOR causes jerks of eye muscles that compensate for jerks of the head and that thereby keep a person's gaze fixed while the person is moving. A shimmering activation models the capacity of a person to look where he or she chooses, e.g., on the basis of memories of images.

Different levels of activation control different kinds of operations. Operations using lower activations (quasi-static and continuous) conform to linear principles, or nearly so, and have simple but limited controls. Operations using higher activations (saccadic and shimmering) behave discontinuously and involve a large repertoire of possible movements, e.g., for possible matching to external influences. Quasi-static activations produce immobile operations; continuous activations typically produce smooth action. Higher activations have more variability and operate faster; conversely, in lower activations, signals have more stability. All activations can produce high intensity motor signals, e.g., maximum signals that produce both centerpoint immobility and kicking movements. What is different between activations are the kinds of changes in signals. Any changes in low level activations occur incrementally; when the activation is shimmering, signals are continually and cyclically churned, perhaps repeatedly resting and starting up refreshed.

Some devices operate with only one kind of activation. Other devices operate with multiple activations. Similarly, in human beings, kinds of muscles have different capacities for variations in movement. Muscular movements of peristalsis in the intestines have only simple variations while fingers and tongue operate with the highest agility. Arm and hand muscles show a high degree of variability and can hold firmly (quasi-static movement), stroke rhythmically or punch. Violinists use arm and hand movements to perform variable intonations, bow-strokes, vibrato and tremolo, resembling movements produced by device designs using shimmering activations.

Suppose that a device system is subject to a shimmering process resulting in delicate selections that are made on the basis of multiple influences. Shimmering operations in one layer can control operations in other layers that have other activations. Hence, after such selections, the process converts or transforms selections into muscular movements that are performed with saccadic activations or continuous activations. During such a transformation, a movement that begins with variable placement and with a weak, tentative force becomes one that is fixed in placement and that is driven by strong, steady forces. I suggest that carpenters driving screws, cooks slicing vegetables and a singer reaching for a high note all employ something similar.

Dogtail movements illustrate the different activations. Positioning movements controlled by ***quasi-static activations*** are steady or nearly so, based on repetitive pulse bundles carried on motor signals and maintained by cycling within muscle modules. In quasi-static positioning, any motor signal change is incremental or tremor-like: a large change is made up of several small changes. Each small change comes to rest before the next small change starts. Separate and independent incremental changes in signals correspond directly to separate and independent incremental changes in shape. It appears possible to fit such changes into mathematical forms called "groups," at least within a range of operations. A null element denotes no change.

Continuous activations operate with motor signals that are always changing in a uniform and periodic way, as in wagging. A certain content is sustained during cycling changes. In simple constructions, movements are controlled by beats. Wagging can vary from slow, low-amplitude movements to fast, high-amplitude movements. Imagery suggests oscillations and waves but movements are actually produced by opposing and unbalanced muscular pulls and controlled by means of unbalanced dissipations. Although some features of wagging resemble traditional features seen in Fourier analysis, no group-like properties of wagging movements are suggested.

Saccadic activations operate with jumpy motor signals and produce jumpy movements. Such movements can have many different forms, e.g., the "cock and kick" form used by the Dogtail that has a "trigger" moment. Such movements can be triggered by a clock or by external events. Saccadic activations often generate more powerful transformations than continuous transformations, like a martensite transformation in steel-making is more powerful than a pearlite transformation. In my approach, the concept of jumpy movements is used to collect fundamentally different or ***disparate*** kinds of activities and a broad concept is used. In other words, a large variety of phenomena can be described in terms of jumps: the collection turns into a grab-bag and a hodgepodge, perhaps even what has been called a *bricolage*.

Ballistic sports movements such as kicking and throwing are saccadic, as previously discussed. Such movements have a "suddenness" or abrupt character, a dramatic focal moment of change modeled by a reversal of signals to opposing pairs of muscles. Hockey and basketball players are skilled in performing sudden reversals so as to frustrate the opponent's anticipations, sometimes executed by means of coordinated action on a team level, e.g., a "fast break."

Extending the concept, material objects of disparate sizes and prices jump into a shopping cart at the supermarket. A trade of cash for goods at the checkout counter is modeled as a pair of jumpy changes in possession of two kinds of "things." Jumpy action includes moving between grades of manufactured products (Good, Better, Best). Similar jumps occur between academic marks (A, B, C or D) or grade levels (3rd grade, 4th grade). In the United States, legal status changes in a jumpy way on a person's 18th birthday. Moving one's personal residence is jumpy or saccadic. Changes in employment or in close family membership are saccadic. Surprises are saccadic.

Suppose that we model a jump by means of a change in location combined with a change in time. In my constructions, "location" is a very broad term and includes street addresses, particular muscles and musical tones. When two jumps between locations occur in close proximity in space and time, they are said to be ***juxtaposed***. Often, a second jump will start from where and when a first jump ends and the two juxtaposed jumps amount to a single jump: then the jumps are said to be ***composed***. A step down a staircase is followed by another step and so forth, amounting to one big step. A connected sequence of jumps or steps can make up a ***course of action*** that has a unitary character and that can, e.g., be compared with other courses of action. Often, a course of action has a purpose or goal. This essay concludes with discussion of purposeful courses of action in actual life, namely, athletic contests and civil trials in courts. Jumps in athletics are simple and step by step; complex jumps in civil trials include motions, objections, dismissals and jury verdicts.

Suppose that the class of jumps under investigation is restricted to those of a single kind that start from and end up in positions that are fixed in location for a duration of time, however short. Anticipating groups, null jumps have zero movement. Jumps in such a class can be organized, at least in part, by means of positioning movements that start from and end up in corresponding fixed positions. Such jumps can also fit the form of episodes that were introduced in § 1(a). In an episode, movements occur within a time period that has a defined starting time and an ending time that can be retrospectively defined. Such a restriction resembles those used in classical mechanics constructions (discussed in § 6(d)) that developed formulations for a restricted class of dynamical movement from static formulations. Here, the restriction leads to a class of jumpy movements that can be represented, at least partially, by a mathematical group. In actual life, brains can control jumpy movements in group-like ways in restricted situations, e.g., in games like checkers and hopscotch. Group elements — e.g., numbers, cycles and ratios — are used to structure activities in baseball, e.g., counting balls and strikes, circling the bases and comparing performances. The group-like character of musical tones in a scale or key is discussed in connection with the timing devices project, "Ears for Harmonic Groups."

The composition principle is also useful for comparison purposes. Suppose an organism first jumps from a to b and then jumps from b to d. Composition matches this with a jump from a to d. Another possibility is that the organism jumps first from a to c and then from c to d. Different ways to jump from a to d can be compared.

In actual life, organized saccadic movements of eyes jump within a range of motion (the field of view) and are said to be "mobile." Such movements of eyes form something like a mathematical group, although confined within limits. Jumpy eye movements occur during some exercises of freedom, while a person is looking around and considering multiple possibilities.

Jumpy performance is often riskier than continuous performance. Continuous performance is under continuous control but the performer loses control, at least in part, during jumpy performance. Some jumps end in landings that may not succeed. The concept of success/failure applies to jumpy action with more dramatic importance than with lower activations. Failure interrupts continuous operations, e.g., "it broke" or "I am tired." More frequent failures are inherent in saccadic activities, e.g., shooting baskets from the foul line and batting practice. If timings, directions and sizes of jumps are varied in a jumpy fashion, the resulting movements may become wholly unpredictable and success or failure may turn into a matter of chance or luck.

Some saccadic movements, e.g., the cocking and kicking movement of the Dogtail, use a two-stage process. Operations in the first stage establish and maintain a large difference in quasi-static activation between opposing body parts, which are held fixed and ready. Then the difference is quickly reversed to trigger or initiate sudden powerful action in the second stage. Such two-stage processes have a preparation or anticipation stage followed by an execution stage. Two-stage processes can take on a shimmering character, e.g., putting in golf. More highly developed four-stage processes handle situations that have continual cycling, like a tennis player practicing serves or a short-order cook. In anticipated device models, four-stage processes use shimmering activations to match movements to forms.

The classes of Dogtail movements and activations have further relations amongst themselves. Each class has a distinct definition but they share limit points and/or overlap each other. A tight fixed position can start to wiggle and wag with addition of a small oscillatory motor signal. Alternating kick movements can become oscillatory if they start smoothly from and end smoothly in mirror-image fixed positions. Shrinking kicks become indistinguishable from tremors used in positioning movements.

The above constructions connect movements to activations. Development now extends to temporal forms. I suggest that each level of activation generates distinct temporal forms of motor signals that produce distinct classes of muscle-like movements. Temporal forms include those observed in reflexes, beats, movement gaits of animals, marching band and traffic engineering. Compare sitting and walking and jumping as representatives of the three lower activations, especially if you think of big jumps like a grasshopper. In muscular activity that is closest to shimmering activation, activity is often based on pre-existing patterns that are held in memory, e.g., throwing a basketball at a hoop, tuning a violin or performing a routine on a balancing beam in a gym. The examples all involve ***focusing*** processes, which are investigated in rudimentary ways in An Eye for Sharp Contrast. In bodily balancing, the gravitational direction is maintained as a focus.

In specific constructions that further development, ***balancing forms*** are used to control certain movements. Four kinds of balancing forms are: (1) ***static balancing forms*** that control positioning movements that are produced by quasi-static activations; (2) ***oscillatory balancing forms*** that control movements similar to wagging that are produced by continuous activations; (3) ***saccadic balancing forms*** that generate and control jumping and kicking movements that are produced by saccadic activations; and (4) ***shimmering balancing forms*** that are generated by shimmering activation and that are used to control or select from multiple possible movements, e.g., during exercises of freedom.

The activity of swimming provides examples. For a person skilled in swimming, balancing in a watery environment is easy and the kind of balancing is easy to change. Static balancing can be maintained while floating on the back. While floating, limbs move only slightly and in a fashion that tends towards an immobile position. Then, a flutter kick with both feet adds an oscillatory balancing form that can be used to steer the body in different directions. Next, if the arms add sweeping motions in and out of the water, using a "backstroke," a saccadic character becomes predominant. Finally, suppose the person switches from backstroke to butterfly to crawl and then to an underwater dive, employing the arts of shimmering activations.

Looking at specific activations and forms of balancing, a biological parallel to the lowest or quasi-static level of activation occurs in the eye during focusing of the eye on an object. (See *An Eye for Sharp Contrast*.) Similarly, quasi-static muscular balancing maintains a momentarily fixed but adjustable opening in the pupil of the eye. As noted above, quasi-static muscular movements hold parts of the body and objects in fixed positions. In each particular "pose" or *asana*, a yoga practitioner relaxes certain muscles while holding other body parts in tension.

Oscillatory balancing is maintained by means of a cycling stream of actual movements that can be continually adjusted, e.g., while bicycling or stirring a pot of food. In oscillatory balancing, the activity has a form where alternating and approximately equal movements on each side are subject to individual adjustments that can change the direction of action in a gradual way. I suggest that walking is chiefly oscillatory.

Quasi-static and oscillatory balancing both incorporate continuity. Both can approximate time-invariance; that is, activity from one period can be detached and superimposed, more or less, on activity of another period and the activities are "the same." That is, they "match."

Saccadic balancing uses one jump to balance another jump. In contrast to static and oscillatory forms, both of which incorporate continuity and time-invariance, saccadic balancing can be abrupt, opportunistic and creative. Please recall discussion of the Hebrew word *regha*' in § 5.1.

I suggest that running is saccadic. A distinction between continuous/walking and saccadic/running is perhaps "arbitrary," like Pauling's resonance theory discussed in § 4(a), but, likewise, I suggest it is useful. The distinction indicates different levels of effort. A typical healthy person can walk continuously, more or less, throughout a day, particularly if trained to do so. In contrast, periods of running are usually brief or limited in duration.

Expanding views of saccadic balancing, revenge or "getting even," is a primal form. The *lex talionis*, "eye for eye, tooth for tooth" imposes symmetry. Perhaps the *lex* limits the violence or interrupts the cycling back and forth. Saccadic balancing can occur in a single prescribed form or in multiple forms, e.g., through mediation and/or a lawsuit and/or vengeful acts.

Some saccadic forms of balancing are based on repeated abrupt reversals of action, e.g., in hockey, soccer or football, where first one side charges in one direction on the playing field and then the other side charges in the other direction. While charging, each side tries to balance and overbalance the charge of the other. Other forms of saccadic balancing occur in markets where money is balanced against goods and services. A downward jump in the buyer's money supply is weighed against a need or desire for the purchased goods or services. Diverse market transactions can be compared and balanced in terms of money. Adversarial and compensatory forms of saccadic balancing are combined when a jury awards money for pain and suffering, providing cash solace for an undeserved injury. The amount of the award will also depend on the personality and person of the defendant who caused the injury, e.g., attractive or obnoxious.

In the domain of brains, the vestibulo-ocular reflex or VOR is an example of saccadic balancing. If you gaze at a fixed object and use your neck muscles to jerk your head right or left (or up or down), your gaze will remain fixed on the object. This occurs even if you keep your eyes closed while you jerk your head. For example, if you close your eyes while gazing at the final word in this sentence, jerk your head and then open your eyes, your gaze will still be here. The VOR accomplishes this task by measuring the head jerk with sensory organs in the middle ear, the vestibular system, and generating signals that jerk the ocular muscles that control the gaze. The size and direction of eye muscle jerks compensate or balance for head jerks so as to maintain the gaze fixed on the object. An invariance (the fixed gaze) is being maintained by balancing one kind of jump with another kind of jump.

The VOR operates reflexively directly between head jerks and eye jerks: there is no need to interpret images or to calculate eye movements on the basis of images. Primary activity of the VOR operates when the eyes are closed or in the dark when there are no images. The VOR is foundational balancing activity that is based in muscular movements, not in images. I suggest that visual imagery stands on a mobile but balanced foundation of muscular activation.

The four kinds of activation thus lead to four kinds of control exemplified through balancing forms. Each kind of control uses distinct kinds of selection:

1. Static control — selections based on comparing sizes;
2. Continuous control — selections based on comparing rates;
3. Saccadic control — selections based on composing and comparing jumps;
4. Shimmering control — selections based on fitting to form.

I suggest that some control processes, especially saccadic processes and shimmering processes, generate ***imagery***, which identifies, indexes and encodes a person's experience, including experiences of sights, sounds, body movements and body positions. Codes for such imagery may be stored in ***memories***. My focus is on imagery that can be so coded and remembered. ***Forms*** are a class of remembered or stored images that are used in shimmering processes. Variable and adjustable forms lead to variable and adjustable muscular movements. Printed sheets of music using standard staves, bars and notes objectify some forms.

"Imagery" is my version of what others call "awareness" or "consciousness." Some questions about imagery are my versions of questions asked by others:

1. How do pulsating material bodies, whether in brains or in new device technologies, generate images that provides a basis for purposeful selections?
2. How do purposeful selections based on imagery lead to muscular movements in animals and persons; or, alternatively, to action-producing pulsations in devices?
3. How do purposeful selections based on imagery connect to a person's actual experience, e.g., to sights, sounds, bodily feelings and muscular movements?
4. What principles can help to develop constructions involving imagery for institutional use, e.g., in organizing materials for judicial management of lawsuits?

I propose answers to these questions. Some of my proposals are only sketches. An obvious shortcoming is that I lack actual operating devices that might demonstrate certain phenomena — or fail to demonstrate such phenomena as the facts should prove.

In my view, current questions of "consciousness" resemble those that led to the development of models of electromagnetism in the era of Hans Christian Ørsted (1777-1851), Michael Faraday (1791-1867) and James Clerk Maxwell (1831-1879). Ørsted moved magnetized needles by switching a nearby electrical circuit on and off, thus identifying phenomena that violated Newtonian mechanics and that first showed a connection between electrical currents and magnetic attractions and repulsions. (Popper & Eccles at 542.) Faraday invented electrical dynamos and motors (interconverting electrical, magnetic and mechanical energy) and imagined ***fields*** to model electrical and magnetic interactions. Maxwell imagined that a changing electrical field generated a changing magnetic field and that a changing magnetic field generated a changing electrical field: ***therefore***, let there be light, along with radio and TV broadcasts and Internet wireless. The metaphor is imperfect but suggestive for the questions stated above. What if streams of action pulses in devices and brains are like electrical currents and what if mental images are like magnetic attractions and repulsions? This would be a "dualistic" solution to the mind-body problem that has received but scant attention in the voluminous literature. (*Id*. at 182, n.3.)

A useful image is provided by Faraday's law of induction: a changing magnetic field produces an electrical voltage or influence. I suggest that changing pulse patterns in Quad Net devices can generate images like the bodily feelings of a person and that an engineered organism can produce muscle-like movements in coordination with the images, leading to production of movements according to forms held in memories. The proposed path of development begins with a model for imagery of musical tones and harmonies as the simplest case. In musical performances and in physics labs, tuned and resonating devices go through repetitive movements that are suggestive of means for generation of such imagery. Neuroscience suggests that musical tones are referable to a "mapping" in a brain. Different ways of moving between tones using musical instruments are suggestive of ways to move between locations in a brain map. I suggest similar models to locate pressure, itch and pain on maps of the body that are laid out in the brain. Feelings of hunger, thirst and sensations involved in other bodily functions can be projected onto appropriate places in such maps. Different positions of joints (noted by James as a source of sensation) can be separately mapped. Such methods lead to multiple image-maps of the body.

Locational maps are static or quasi-static. Models of movement require overlayers. Preliminary overlayer of development are directed at models of feelings of stretch in muscles, as in yoga poses. Coordination of stretches in different muscles to maintain a certain bodily position resembles coordination of different tones in music to maintain a chord. Models of both kinds of feelings use devices to generate ratios in the style of Pythagorean harmonics.

Movements involve changes. Changes in locational sensors in joints can be coordinated with changes in stretch sensors in muscles to generate a unified pattern that can be repeated. Movements can be located with respect to body-maps, e.g., in models of itching and scratching, as a primal form of "Ideo-Motor Action."

Developmental principles suggest larger organizations of images and wider repertoires of control. Disparate kinds of images must be accommodated. Further development would include models of specific bodily movements that have multiple layers and purposeful courses of action.

I suggest that a person's imagery is not of a single kind nor is it based on a single set of principles. Rather, imagery is generated in disparate layers and with various inter-layer patches. Some layers are generating muscular movements that interact with image-generating layers, e.g., through matchings of cyclical operations. There are streams of imagery that start and stop, that remain steady or vary and that are sometimes independent and sometimes entrained. Images are blended under some circumstances and distinguished under other circumstances. Depending on situations, imagery may be or may not be subject to organization, to different and conflicting organizations and to re-organization. While a person may seek to unify or integrate his or her imagery — for ease of application, among other reasons — progress toward such integrity is an ongoing task that is never fully achieved.

I suggest that persons use imagery called "forms" to make selections, e.g., "stop on red, go on green." Such formal selections require more than the "awareness" of an organism that is alert and active. For example, a motorist waiting at a traffic light must consciously notice a change in the bright color in order to move his foot from the brake to the accelerator. If the motorist is not "paying attention," another motorist may enlarge the range of his awareness by blowing a horn.

More generally, selection processes can be influenced in multiple, diverse ways. I suggest that in memories we have forms of selections we made in the past and that we use those forms to help make selections in the present. For example, I suggest that we use something like Shimmering Sensitivity to decide between forms of dinners, represented by words on a restaurant menu. The first attempt to fit to form may be repetition or reconstruction of a memory of a prior meal. Such a reconstruction may succeed in the present situation. If not, maybe imagery can be modified by swapping pieces taken from other memories.

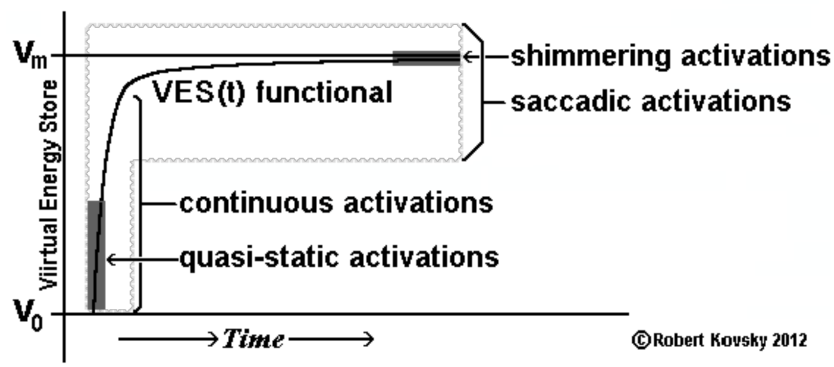
Development of models leads towards a background of continuously cycling operations that are interrupted or modified by saccadic moments of imagery that flicker in multi-layered and patched neuronal mappings of body parts, tracking body positions and movements and also arising through body-imaged drives like sex and emotions. I suggest that we share with reptiles and other mammals the greater part of such continuous operations and saccadic imagery. Repetitive and familiar situations and accumulated memories of similar occurrences give a more solid constitution to such flickerings. We know what we are doing because we have done it before. Imagery further develops through forms, such as forms of family, language, sports, music, mathematics, popular culture, technology and institutions. Such forms control personal lives and the character of a community. The history of human civilization shows the power of spiritual imagery and of spiritually-inspired forms as controllers operating at the highest levels.

In sum, a flickering foundation of body-based continuous and saccadic imagery is given solidity by repetitive situations and resonant memories. The foundation is overlaid with more finely-detailed shimmering imagery that is attached to the foundation but that also responds to diverse external influences, to forms and to detailed memories. In a larger perspective, all such imagery depends on collective activities of human beings working together in a civilization. We depend on a global biological environment that sustains the repetitive situations needed for actual life.

I suggest that the solidity and self-knowledge that accompanies personal bodily experience is based on unifying resonances in multiple parts of multiple layers of brains and that such resonances arise in recurrent remembered situations that sustain repetitive activity. Organized operations can be partly static, partly continuous, partly saccadic and partly shimmering. It is through shimmering activity that we exercise freedom and it is through recurrent, fixed, continuous and saccadic bodily action that shimmering activity and exercises of freedom can influence actual life.

The following constructions use mathematical and engineering forms. The Quad Net VES(t) functional shown below organizes the four activations. Continuous activations develop smoothly out of quasi-static activations. with simple enlargements of repertoires. Although shimmering activations develop out of saccadic activations, selective shimmering processes are different from execution processes used in saccadic activations; and repertoires of selections generated in shimmering processes appear to be wondrously abundant. There is a cross-over region between continuous activations and saccadic activations. Plans for the next project, *Feelings, Forms and Freedom*, start with quasi-static and continuous operations in linear regions of the functional that are controlled solely by internal variables. Then, the repertoire of operations is enlarged by adding saccadic movements that are responsive to external influences.

Levels of Activation organized by means of the QN VES(t) functional



Such constructions suggest that the hitherto-mysterious generation of imagery can be modeled by the physical principle of Shimmering Sensitivity. Proposed Toroidal Quad Nets (TQN's) go though repetitive cycling "shimmering processes." Shimmering Sensitivity arises at critical moments in shimmering processes. Its character is flickering rather than steady – similar to the twitch of a muscle fiber and to the impulse of electromotive force generated in a wire loop by the sudden appearance of a magnetic polarity. (Faraday Law of Magnetic Induction.) Shimmering Sensitivity can be sustained, in a flickering fashion, in arrays of TQNs, through cycles of critical moments that carry waves of content. I suggest that a piano or a symphony orchestra generates similar imagery in similar ways. Calvin used such metaphors in his book *Cerebral Symphony*.

The principle of Shimmering Sensitivity is based on laboratory studies of physical systems that pass through a ***critical point***. In such systems, as a hot body cools, there is a specific kind of transformation that occurs at a specific temperature called "the critical temperature." Such ***critical point transformations*** occur in a large class of physical and material systems and they have been successfully investigated both mathematically and in the laboratory. Cyril Domb was a pioneer in critical point physics and wrote an excellent technical review, *The Critical Point: A historical introduction to the modern theory of critical phenomena* (1996).

Materials that go through critical point transformations include water and other fluids, brass (an alloy) and iron magnets. Such a collection is ***disparate***; as a class, the materials and phenomena have little in common besides critical point transformations. Critical point transformations are a special kind of phase transformation, resembling but also different from pearlite/martensite and snowflakes. Critical point transformations present features in common with the general class of phase transformations such as discontinuity and complete change of form. In addition, critical point transformations have special features. In critical point transformations, discontinuity is very subtle and form changes can be highly mobile. A critical point transformation occurs only at a specific temperature — e.g., the critical temperature or Curie Point Temperature for pure iron magnets is a single highly specific number near 770 °C. In contrast, in a more common kind of phase transformation, liquid water will transform to ice at any temperature below 0 °C.

At their respective critical points, disparate materials have important features in common. Away from the specific critical point, activities of disparate materials have essentially nothing in common. Common features in widely disparate critical point systems establish a principle called ***universality***. Universality in critical point physics is different from universality in platonic physics. Universality in critical point physics means that all the systems share certain properties when they are at the critical point. They do not share properties otherwise. Appearances of universality in critical point physics are highly local in space and time; they control only certain events rather than "everything," as in platonic science.

Another feature of critical point systems is ***non-local correlation***. Activity is full and plenary so that movements affect each other over large distances, e.g., through waves and cycles that interact across a field. At the same time, there is enough space for movements to actually take place. It is like a heavy "stop-and-go" traffic condition where cars move in accordion-like crawling, too many cars for easy flow but not so many as to result in a complete jam.

As discussed below, critical point systems can perform selections. Principles of universality, non-local correlation and selection are combined in device operations. I suggest that such device operations also generate flickers of imagery.

Accordingly, I suggest that multiple device modules with differing designs can go through shared critical moments during which multiple selections are made together and in a unified way. I suggest that collective, nonlocal and synchronized critical moments are the answer to the binding problem discussed above. I suggest that the universality of critical moments is reflected in the nature of experiential imagery that has multiple forms co-existing in a person's imagination, e.g., in metaphors and analogies. Also many jokes, e.g., puns. Please compare such suggestions to Baars' global workspace.

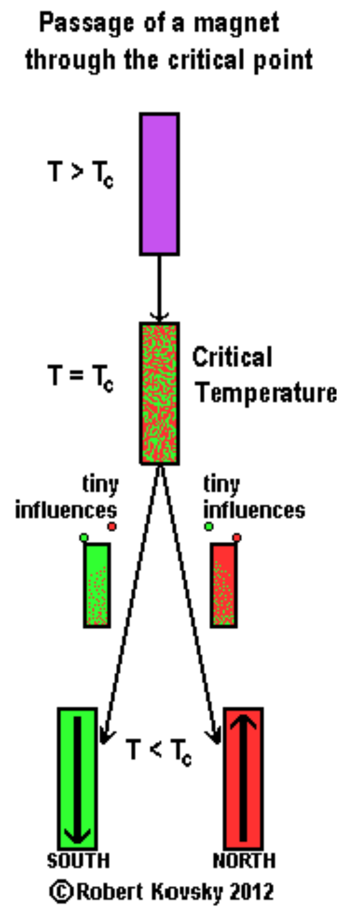
Principles of construction suggest that: multiple action pulses add up to a unitary pulse bundle; multiple muscle fibers add up to a unitary muscle module; multiple saccadic jumps add up to a unitary course of action; and multiple selections in different devices and having different forms but sharing a single, interconnected critical moment of synchronous selection add up to unified imagery that can be partially indexed, stored and reconstructed though processes of memory.

Additional aspects of critical point phenomena contribute to my designs. The paradigmatic system made up of liquid water and steam resembles an Ideal Gas at a limit in the range of possible conditions; the system passes through the critical point at another place in such range. A thermodynamic process that carries water from the critical point to an Ideal Gas would parallel operations of a device system that converts delicate selections into strong muscular movements, such as a device system suggested above that might model "free will."

Critical point systems and the Ideal Gas occupy limit points in a range of operations. Within a system at the critical point, changes are always ongoing. Such a system never relaxes, unlike equilibrium systems that are completely relaxed. (Please see my *Patchwork Of Limits: Physics Viewed From an Indirect Approach* (2000).) Each limit point has a mathematical model, pV=RT for the Ideal Gas, as previously described. Critical point activity is described by the ***Ising Model***.

Lars Onsager, the previously-discussed winner of a Nobel Prize for his reciprocity relations, provided a closed-form mathematical solution for the Ising Model that led to "revolutionary" breakthroughs. (Domb.) The Ising Model uses statistical mechanical or "thermostatic" forms based on energy conservation. The Ising Model was the starting point for design of the Quad Net Model of brains. However, the QN Model uses dissipative processes. Academic discussion of critical point phenomena is reconstructed here for use in episodic balancing forms.

The Figure below shows the passage of a magnet through the critical point or temperature, T_c, also known as the Curie point or Curie temperature. Research institutions maintain online computerized demonstrations of the Ising Model. As shown in such models, when the system is fixed at the critical point, phasic aggregates of particles are continually coalescing and dissolving. At the critical point, there is rough ongoing balancing between coalescence and dissolution.



A magnet held at a temperature above the critical point has no intrinsic polarity. That is, it will not orient with respect to an external magnet. When the temperature of such a magnet falls sufficiently below the critical point, it can acquire a north polarity or a south polarity. Only a small drop in temperature is needed.

Suppose an episode begins with the magnet held just above the critical point. Then, the temperature drops to the critical point. Finally the temperature falls below the critical point.

At the critical point, both polarities co-exist within the magnet in transient aggregates that are continually coalescing and dissolving.

Symmetries show that it is equally likely for the cooling magnet to turn into a north magnet or a south magnet. A ***tiny magnetic influence*** will select either north or south. As the cooling continues, the magnetic polarity becomes fixed.

At the critical point, $T=T_c$, it is very easy to shift the magnet's polarity back and forth from south to north. The magnet is very weak. When the temperature of the magnet falls below T_c, the polarity becomes fixed and the magnet is strong.

Critical point principles are applied commercially in magneto-optical memory systems. Tiny magnetic elements on a disc store digital information. When appropriately directed, a laser heats up an element so that it is erased and re-set by an external magnet.

An important special feature of critical systems is that activities at different spatial points within such a system affect each other regardless of distances between points. Activity is so highly activated and so congested that a fluctuation at one point can connect with fluctuations at distant points to sweep over the entire interconnected region in a shimmering way. I suggest that such ***nonlocal*** critical point activity is a basis for the binding principle discussed above.

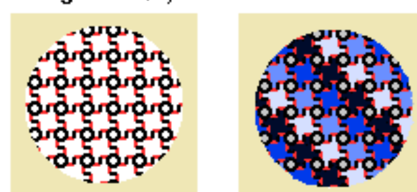
My large-scale brain models are based on G. M. Edelman, *Neural Darwinism: The Theory of Neuronal Group Selection* as to important features. In the models, a brain includes a large number of smaller compact bodies that are themselves made of neurons. Such compact bodies, e,g,, bodies of neurons with names like nucleus and ganglion, are called ***neuronal groups***.

Edelman shows that there are thousands of neuronal groups in a human brain and that they are interconnected through nerve tracts that are like bundled cables of wires. Some neuronal groups send motor signals to muscles and some neuronal groups receive signals from sensory organs. A large functional unit inside a brain, e.g., the central thalamus, can be viewed as a clustered and layered structure of interconnected neuronal groups. The cerebral cortex is a larger structure that is similarly constituted of interconnected units. Neuronal groups apparently work together and scientists declare that there must be integrating principles. (Koch, Edelman & Tonini.)

Activities of neuronal groups are studied using "functional Magnetic Resonance Imaging" or fMRI that monitors the distribution of sugar carried by blood and consumed by neuronal groups. Using such techniques, it is observed that, in a brain occupied with a specific task, some neuronal groups are highly activated and some neuronal groups have low activation. The set of highly activated neuronal groups is specific to the task; change the task and the set of activated neuronal groups changes. E.g., different sets are working when the person is engaged in sports, musical performance or committee meetings. Such a set of neuronal groups that are highly activated with respect to a specific task is called a ***coalition***.

The adjacent image shows Quad Net or "QN." A spatial array or field of "elemental devices" constitutes QN. Each device is connected to four neighboring devices. A pulse discharged by one device triggers neighbors that are ready. For example, pulsational activities generate waves of pulses within the material, as illustrated. Repetitive pulsational activity can be maintained in diverse forms, which are collectively called a ***repertoire of phases***.

Image 1: QN, an activated material



a. spatial array b. activated QN

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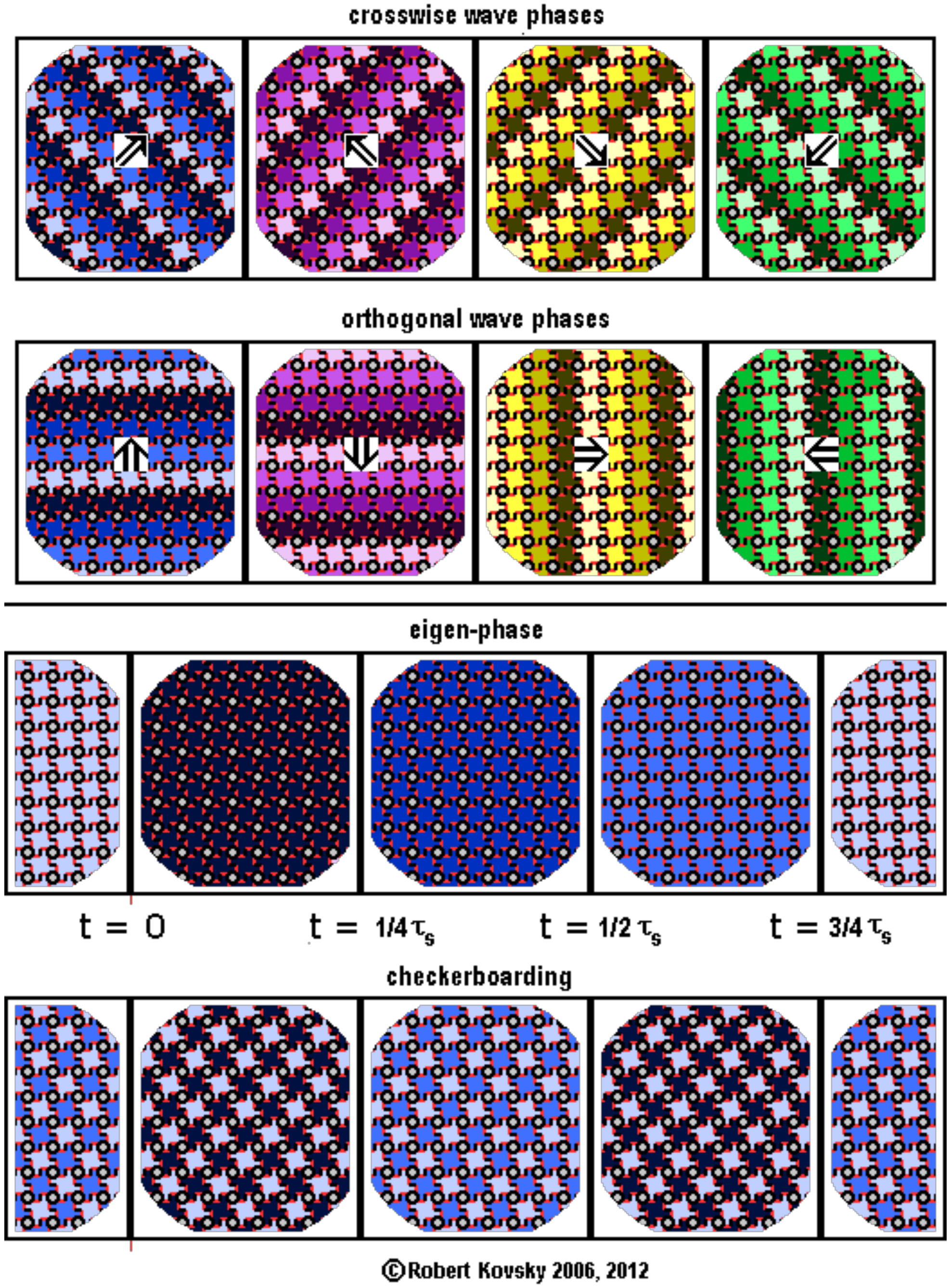
Simple Quad Net operations can sustain a repertoire of cyclical phases. A repertoire of phases is shown in imagery on the next page. There are eight wave phases (four crosswise phases and four orthogonal phases) and two collective phases (the eigen-phase and checkerboarding), Each of the eight wave phases includes a polarity or "direction of travel." To imagine the direction of travel, the brightest elements (which are in in a "responding condition" and getting ready to discharge a pulse) are "moving away from" the darkest elements (which just discharged a pulse that triggered the response). Actually, of course, nothing is moving and colors of images denote conditions of elemental devices in the Quad Net field that are going through cyclical processes.

Operations discussed below are restricted to crosswise wave phases and the checkerboarding phase. In a crosswise wave and in checkerboarding, an element is triggered by two (or more) discharges from neighboring elements that occur within a "ready" time period that is much shorter than the period of the wave; the devices follow a "two-pulse trigger rule." The eigen-phase can also be maintained if devices follow a two-pulse rule. If devices follow a "one-pulse trigger rule," all the phases can be maintained.

Image 11 (Revised): Repertoire of phases in Primal Quad Net



In checkerboarding, half of the devices in the field pulse together and then the other half of the devices pulse together. The halves are like red and black squares on a checkerboard. Pulses in each half-field are triggered by pulses from the other half-field. A relatively lengthy period of time passes between the triggering of a device and its pulsation ($\frac{1}{2}\tau_s$); meanwhile, the other half-field becomes ready. At any instant in checkerboarding, half the devices are responding.

In wave activity, a first device does not become ready to receive a pulse produced by a second device that the first device has triggered. The first device becomes ready only after the second device has pulsed and the first device must wait for the cycle of pulsations to come around again. In a wave phase, a device is in a responding condition for only a minor fraction of the wave period. If wavelengths become progressively longer, the fraction becomes progressively smaller.

In a process that generates Shimmering Sensitivity, shown on the next page, a device passes from the checkerboarding phase into a wave phase. The checkerboarding phase is symmetrical but the wave phase is asymmetrical. Multiple possible wave phases turn into a single actual wave phase. Hence, the process operates so as to carry out a selecton. The passage can be continuous and fully controlled or it can be carried out in a jumpy fashion. The actual result may depend on whether the passage is continuous or jumpy.

I further suggest that, in addition to the function of making a selection, the passage can generate an image that encodes the selection. Similarly, I suggest that a person experiences the making of a selection in actual life and that the event is recorded in memory.

Turning to technical details, Quad Net is conceived of as an elastic, rather plastic material that can handled and shaped for specific purposes. Accordingly, Quad Net can be stretched and interconnected to form certain shapes, of which the most important here is the Toroidal Quad Net or TQN. Images from the *Quad Net* paper illustrate such construction methods. Construction methods are intended to be congruent with development of neuronal tissues of an animal in the uterus. (Edelman, *Neural Darwinism* .)

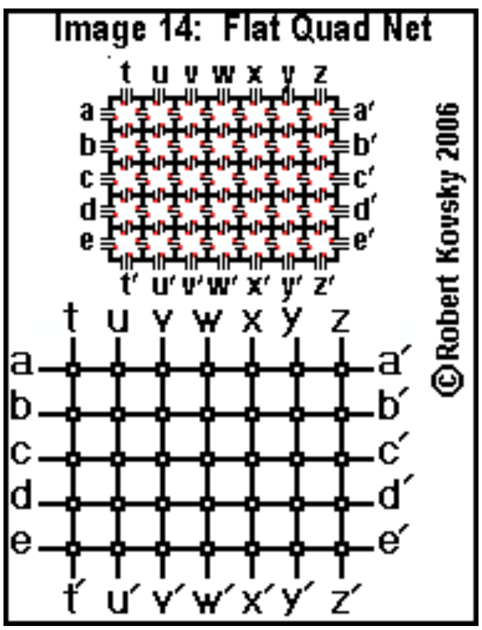


Image 14: Flat Quad Net

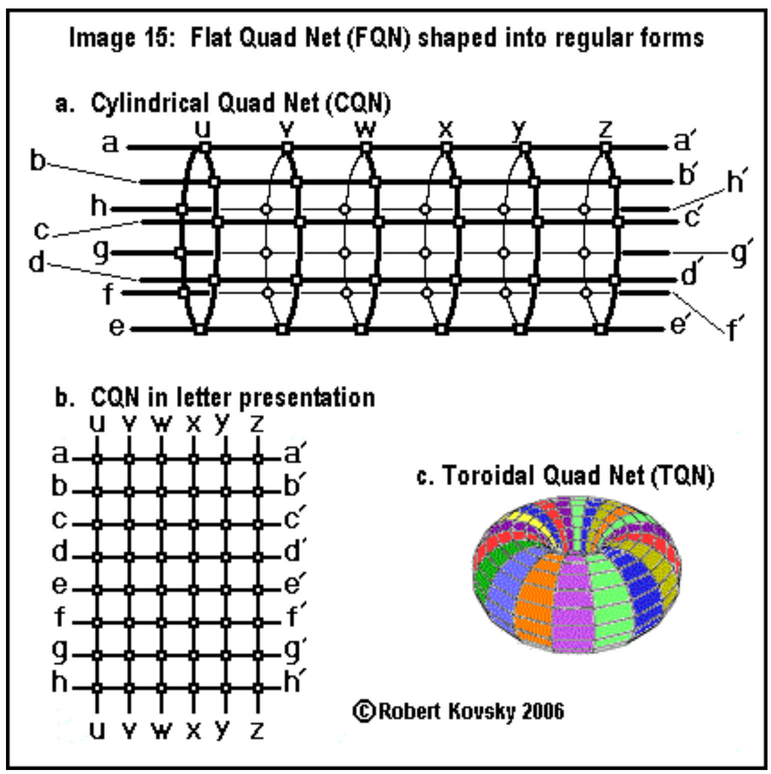
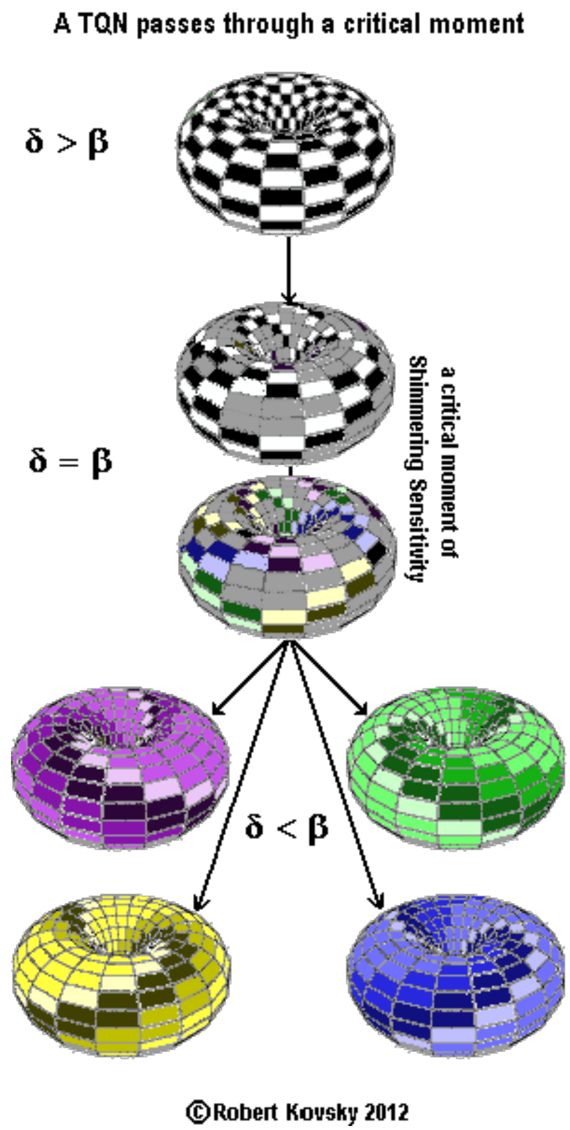


Image 15: Flat Quad Net (FQN) shaped into regular forms

Operations of a Toroidal Quad Net (TQN) shown in the adjacent image, depend on values of timing intervals δ and β. The timing interval δ is the period of time between the triggering of an elemental device and its discharge. The timing interval β is the period of time between the discharge of a device and its return to readiness. The timing interval δ is called "the responding period" and the timing interval β is called "the refractory period."



When δ > β, an elemental device that discharges and triggers a neighbor will return to readiness before the neighbor discharges. The triggering device will get through β faster than the triggered device gets through δ . The resulting pattern is "checkerboarding" or alternating discharges.

When δ < β, a device is still refractory when it receives a pulse from the neighbor it triggered; it does not respond. Activity takes the form of waves. Steady stable crosswise wave activity in the TQN occurs in exactly one of four directions. As with other collections of ticking clocks, ***entrainment*** unites devices into one pattern.

Critical point processes in TQN's resemble those seen in magnets. A shifting relationship between δ and β leads to a moment when δ = β, the critical moment, when relatively weak signals from other devices generate and select the final wave pattern in the TQN, which is then maintained for the rest of the cycle.

In other words, passage of a TQN through the critical point generates a critical moment of Shimmering Sensitivity. At the commencement of the critical moment, activity in the TQN can appear as germinal "wavelets" moving in multiple directions. As in magnets at the critical point, aggregates coalesce and dissolve according to external influences. While coalescence and dissolution are occurring, there may be shimmering or jumping from pattern to pattern.

As the cycle continues, and as a result of unbalanced external signals, wavelets in one direction unite and take over the TQN, establishing simple waves. Because, at the outset, any of the patterns is equally possible, the selection is highly sensitive to external influences. All kinds of influences may affect the selection, including operational variations in the process.

I suggest that TQN's and other device parts can be organized in systems that maintain ongoing coalescence and dissolution of wave patterns. I suggest that advanced layered devices can circulate continually evolving patterns of coalescence and dissolution.

When activities of interconnected TQN's and other device parts are synchronized, they pass through critical moments together. During a critical moment, local activity within one TQN generates nonlocal activity in other interconnected TQN's and vice versa. Assemblies of devices organized into momentary coalitions can generate a condition of shimmering in which resonating aggregates of activities in devices coalesce and dissolve.

An influence that reaches a coalition through one TQN may affect selections in many TQN's in the coalition. One set of patterns may be steady while other patterns go through changes that are subject to the steady patterns.

Shimmering can extend over an entire synchronized coalition: then, as the critical moment passes, disparate selections occur simultaneously in stages in different subsystems. Perhaps the body of selections is organized as a whole through collective power of entrainment. Then, as the critical moment passes and activities in interconnected TQN's and devices are selected, they separate from each other and become independent, each confined to a specific domain. The coalition breaks apart into smaller coalitions and each smaller coalition takes on a selected character. Mirroring coalitions can sustain one version while another version changes. Such activities may be repeated through cycling activity. In steady operations, a temporary or permanent hegemonic pattern may appear.

I further suggest that critical point operations show how individualized imagery – a person's conscious experiences of movements, feelings, positions, sights, sounds and forms – might be generated during phase changes in pulse patterns in neuronal groups in brains and have consequential power. I suggest that experiences of a person during a psychological moment of now are generated by passages of material bodies through a critical point that are modeled as critical moments of Shimmering Sensitivity. The leap from phase changes in pulse patterns to experiential imagery is, obviously, highly speculative; but it seems clear to me that ***something*** is generating such imagery in my own brain – and phase changes and pulse patterns offer leadings for development that have been fruitful for me.

I suggest that such imagery — generated and sustained by synchronized and resonating coalitions of spatially-spread-out, interacting neuronal groups in a brain — has a precarious but compact existence with a complex, mobile interiority that can be identified with a person's self. Within such interiority, one kind of imagery, such as forms, can be invariant and in apparent control of activities, while movements or other images are modified to conform thereto. I suggest that courses of action can be made subject to overall control of such a self, that is to controlling forms originating in childhood training and maintained by habits in a bodily and social environment. The controlling and maintained forms make up a personality. The person develops and maintains controlling forms of personality and self for the sake of doing it.

In other words, persons, or, at least, young persons, can be trained to generate and sustain mental imagery of specific forms of behavior and to exercise self-control through use of such forms in suitable environments. I suggest that in actual life, most persons exercise such self-control through personal choice and through selections of environments. Judgments of legal, social and moral responsibility are based on the capacity of a person to generate and sustain in mental imagery certain forms of behavior (stop-on-red/go-on-green) that are mandated by family members, by society and by other influences and to follow those forms when changing possible bodily movements into actual movements. (Didn't Plato say something similar?)

f. Sports competitions and civil trials illustrate adaptations of strife to episodic forms of balancing. Such forms lead to transformational critical moments, e.g., moments of overtaking during footraces and moments of decision by judges and juries in courtroom proceedings.

In this subsection, principles previously developed are applied to large-scale events of actual life, namely, episodes of balancing that occur in racetracks and courtrooms. Discussion of a footrace focuses attention on a particular event. Discussion of lawsuits extends into wider views.

The events being considered are exemplars of domesticated ***strife***. Strife in actual life is often difficult to domesticate, that is, to bring under control of forms or laws, but some progress has been made. My approach starts with some general observations.

In many episodes of strife, animals fight for possession of a ***prize*** — a carcass or a battleground highpoint or an Olympic medal or a court judgment. Each fighter wants both to win the prize and to prevent competing fighters from winning the prize. Fighters try to anticipate each others' moves with respect to the prize and act to frustrate others' attempts to gain the prize, seeking to "beat" or "beat out" the others. The Greek word for prize is *athlon* — hence our "athletics."

Episodic balancing forms that culminate in prizes are used in sports competitions and civil trials. Such forms of balancing incorporate principles of symmetry and invariance that actually control and resolve strife in these domains. In actual life, I suggest, it is not music that quiets the savage beast, but prizes gained through controlled strife in contests that use episodic balancing forms.

According to de Santillana, Heraclitus (c. 500 B.C.) was "the philosopher of unresolved strife." Heraclitus wrote: "War is the father of all and king of all," "strife is justice" and "all things come into being and pass away through strife." De Santillana interprets: "There are great oppositions and polarities of nature, of which sex and war are only the too-visible symbols." (46.) Heraclitus' influence hung over Plato and other Greek philosophers who took very different approaches. Heraclitus "focused attention on how mysterious and ambiguous the objects of nature really are, however familiar and obvious they may appear to be." (49.)

Empedocles (c. 450 B.C.) constructed a system in which "Earth, Water, Air and Fire … behave as passive matter, for there are also two opposite forces that move them around, positive and negative, Love and Strife." (109.) "By concentrating on the invariant background of matter and force, Empedocles is led to treat events in a quasi-statistical manner, which draws on him from Plato and Aristotle the reproach of having brought in chance and eliminated purpose." (116.)

Platonism is supposed to quell strife, at least internally. Platonism presumes the omnipresence of a single-minded and hegemonic set of principles that can be declared by an institution of authoritative knowledge from which strife has been banished. Platonists often express an aversion to strife; and those with personal aversions to strife often adopt platonism.

Platonism breeds rebels. Among rebellious philosophers, Nietzsche is famous for glorification of strife. "*Out of life's school of war*: What does not destroy me, makes me stronger." (*Twilight of the Idols*, Maxim 8.) In "Homer's Contest," Nietzsche wrote that for ancient Greeks, "the contest is necessary to preserve the health of the state." If "the contest would come to end…the eternal source of life for the Hellenic state would be endangered." "And just as the youths were educated through contest, their educators were also engaged in contests with each other. The great musical masters, Pindar and Simonides, stood side by side, mistrustful and jealous."

Other ancient texts also glorified strife. Major episodes of glorified strife in the Hebrew Bible include liberation from Egyptian bondage, the Conquest of the Homeland and wars involving Israel, Judah, Assyria and Babylon, sometimes said to be the will of the Lord. Strife is central to family stories about Cain vs. Abel, Isaac vs. Ishmael, Jacob vs. Esau, Joseph vs. his brothers and King David's sons vs. David and each other. The Hindu epic, *Mahabharata*, is a massive, grand and glorious saga of peace and war and peace; one overall theme is that the heroic race of kings and warriors killed each other off, leaving priests and professors to run things.

Modern approaches to strife use concepts that do not fit together. Psychologist Alfred Adler (1870-1937) broke off his close association with mentor Sigmund Freud (1856-1939) and emphasized competition among siblings. (Kaufmann, Discovering the Mind, v. III.) A 20th century strategist, Capt. B. H. Liddell-Hart, generalized the history of wartime military decisions into metaphysical principles in *Strategy: The Indirect Approach*, which have become obsolete in an age of asymmetrical terrorism and fissaparous populations. Every county government in the United States, or nearly so, has a publically-accessible law library filled with materials used in resolving contested matters in court. Those involved with communal peacemaking often rely on principles and practices of non-violence originating with Mohandas Gandhi and Martin Luther King, Jr. See, e.g., Slattery et. al, *Engage: Exploring Nonviolent Living* (2005).

None of the approaches has provided solutions to problems of strife outside of narrow domains. Given inherent difficulties of the topic and many diverse approaches, my approach is to narrow the focus of attention and to try to connect to actual life. Our need for new ways to deal with strife identifies important long-range goals for development. Constructions herein use balancing principles to model cases of strife that are resolved through the governance of institutions.

Balancing activity is grounded in symmetry. More precisely, balancing activity establishes and maintains symmetry and, while successful, ***maintains a balance*** that can be stated in terms of symmetry. Extending the investigation, balancing activity can also include a ***loss of balance***, which is a termination of symmetry that also terminates the activity of balancing. In processes that involve Shimmering Sensitivity, loss of balance is as important as maintenance of balance. In devices that shimmer like TQN's, balance can be lost in multiple possible directions but balance is actually lost in exactly one direction. Once balance is actually lost, it can be restored with minimal costs, under some circumstances, making continuous operations possible. Meanwhile, each actual loss of balance can be converted into selective muscular movements, perhaps first pushing in one direction and then in the opposite direction, to restore balance.

As stated above, an episode is a course of action with a starting time and a time of completion. E.g., a ***life*** is an episode. Each episode is separately produced and has distinct features, e.g., a unique lifetime that stretches from birth to death. Only ***individual episodes*** are produced. It is not possible to produce the exact same episode twice and differences between any two episodes can always be detected, in addition to their having separate identities and different starting and completion times. In other words, individual episodes may not fit into invariant forms that disregard individual differences and that try to treat different events "the same."

An idealized episodic balancing form has a time prior to its existence, a point in time of its establishment, a period of contention or running and a point in time of its termination. At the commencement of the running period, two or more possible outcomes co-exist in a symmetric and balanced way. During the running period, balanced possible outcomes at the start turn into one actual outcome at the end. Multiple possible winners have turned into one winner. One winner excludes all others from winning.

Individual instances of episodic balancing contrast sharply with invariant forms of platonic science such as forms based on conservation of momentum and energy. Instead of a hegemony of impersonal invariants that mandate determinate results except when they don't and then it's chancy chaos — with episodic balancing forms, outcomes turn on moments of uncertainty that are subject to conflicting influences such as unexpected triggers, competitors and deadlines.

Although every episode is different, episodic forms are sometimes suitable for incorporation into a ***tiled*** temporal form, which can approximate invariance. Tiled forms are repetitive and cyclical and they also hook up end-to-end to generate ongoing activity that can become self-perpetuating. A typical tiled form is a sequence of episodes that resemble each other in certain respects. Some tiled episodic forms, e.g., an anniversary, are simply repetitive. In complex tilings of episodic balancing forms, e.g., tournaments, a general form of activity is repeated cyclically but specific details are varied during the repetitions so as to allow for a large number of possible winners.

In other constructions, individual episodes are composed into a sequence that constitutes a course of action. Perhaps a progression of episodes in a drama leads to a climax, which is a culminating and transformational episode. Individual law cases, each an individual episode, add up to a trend in jurisprudence. Through decisions in marketplaces of politics and consumer goods, I suggest that individual episodes of balancing can add up to large scale activities of a civilization.

Balancing principles are illustrated by a formal footrace in a sports arena. For particular features, imagine a mile race or a 1500 meter race that takes about 4 to 10 minutes. Perhaps the runners are students.

Strife in a footrace is constrained by formal features that incorporate principles of symmetry and invariance. The geometry of the track gives every lane of travel closely-similar opportunities so that contestants should be indifferent as to lane assignment. Contestants stand as equals before neutral officials and neutral rules. Rules are the same for all contests of a specific kind regardless of where or when the contest is held.

During a race, each contestant engages in action that has a similar course. The race starts according to a signal that is common for all runners and finishes at a common line. The competition is for "who runs the fastest," a contest of average speed. The only measure of speed that matters is the quantity of time required to run from the starting signal to the finish line. Because of the commonality of such features, comparison of contestants' speed can be made directly, according to the order that they cross the finish line. The first to cross "wins" the race and winning is the purpose of each runner. Only one runner can win and runners try to exclude each other from winning or to "beat" the adversaries. Each runner seeks to inflict defeat on all other runners. The conflicting purposes of the runners are the basis for strife in a footrace.

The foregoing symmetrical and invariant features provide a system of constraints for a footrace, or, in other words, a ***form*** for a footrace. The character of a race as a "fair race" depends on the occurrence of such formal features during the actual event. Formal features make a footrace suitable as an event in the life of an institution such as a college that hold sports competitions. The racetrack incorporates spatial forms of geometry that are universally accepted. Rules incorporate the rigidity of invariant symmetry, always to be strictly applied the same to all persons. When races are run according to such forms and rules, runners accept the outcome and return for more races. Institutions, like babies and scientists, do things for the sake of doing them. Helping to bring such forms and rules into existence, adhering to them and organizing activities to conform to them are functions in the life of an institution.

The invariant, symmetrical track and rules only provide a container for the actual running of a footrace. In *The Crucible* (1992), available on my website, I compared institutional activity of a court to activity of a metallurgist inventing a new alloy. The metallurgist uses a fixed, stable material container – a crucible – inside of which various ingredients are mixed and melted together. The stable crucible provides a container for phase changes in metal alloys. I suggest that a court is like a crucible; it is a place for combining and mixing and modifying ingredients to arrive at a judgment. Likewise, I suggest that race tracks serve as crucibles for sports competitions that lead to a winner.

An actual footrace is controlled by temporal forms. From start to finish, the race is one extended period of time that fits the episodic balancing form. A particular race contest is usually set in a context that includes other race contests; perhaps the context is called a "meet." The meet may include 10 or 20 or so separate race contests. Each particular race episode has a starting time and a time when it has been completed. No actual racing occurs before the starting time or after the time of completion. The race is completely performed within a compact period of time that makes up the episode.

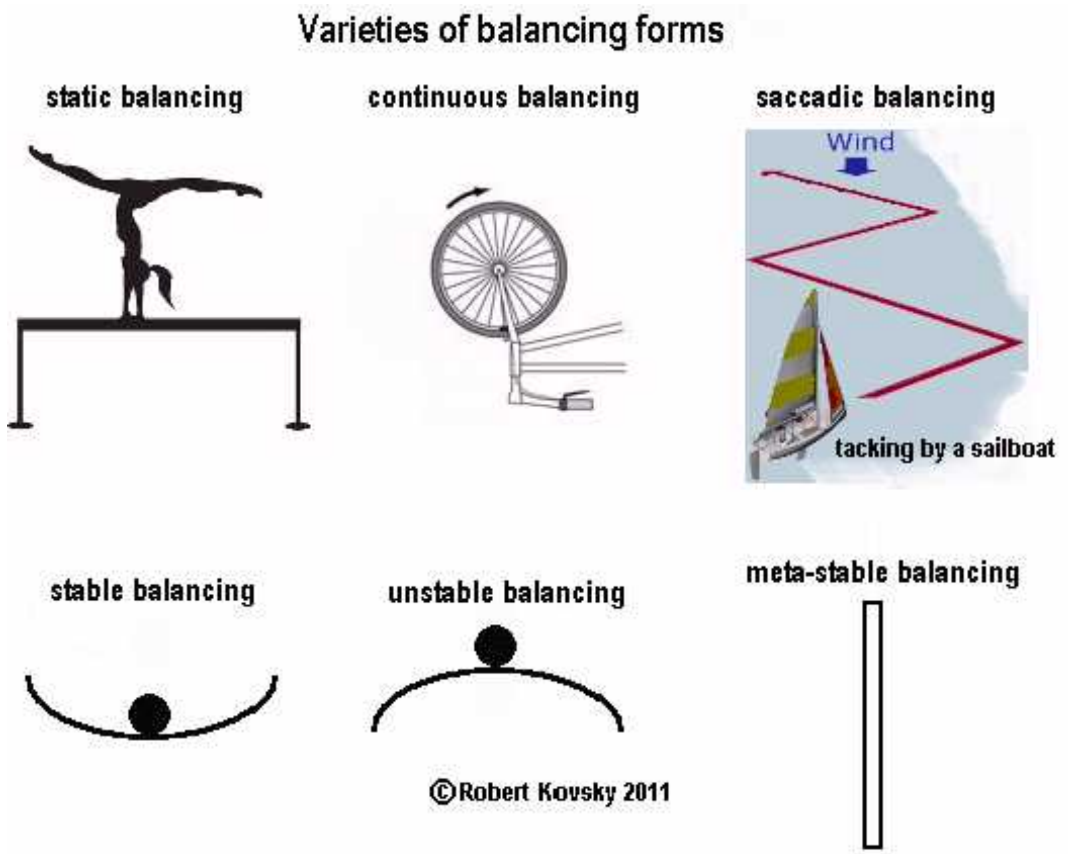
To highlight episodic balancing forms, I consider a race with only two contestants, "he" and "she" and presume that he and she are roughly matched in training and speed. A few "special moments" divide the running period into compact periods that are made up of "ordinary moments." At "ordinary moments," exactly one runner is in the lead. "Special moments" include moments of overtaking or challenge when no one is in the lead.

Although the underlying racetrack and rules are symmetrical, the focus of the race is on asymmetry. In the simple race, there are two possible final asymmetries, one where he wins and one where she wins. In such a simple race, during the running period, asymmetry is followed by noting, at any particular moment, "who is in the lead." Suppose that right after the starting signal, he takes the lead. (A symmetrical discussion applies if she takes the lead.)

There are three possible large-scale temporal forms for the race. First, during the course of the race, she passes him and wins the race. This temporal form of race is called "overtaking." In the second temporal form, the "leads all the way" form, she does not pass him, even though she may challenge him, and he wins the race. In a third temporal form, the "see-saw" form, she passes him, then he passes her, then maybe she passes him and then maybe he wins and then maybe she wins. The forms and distinctions between forms are based on moments when one runner passes or overtakes the other runner. Such moments are like phase changes in materials, e.g., when water changes into ice. During a moment of overtaking, the activity changes in a fundamental way, like when a magnet changes from North to South.

Suppose that the action in a particular footrace features overtaking at a single central, critical moment. During the moment of overtaking, the runners are in symmetrical positions, equally distant from the finish line. On the other hand, the speeds are unequal as one runner is moving faster than the other. The form of action combines symmetry and asymmetry.

As shown in the Figure below, some temporal forms of balancing can be represented by an iconic or symbolic form and a name or verbal form. Forms of balancing previously discussed are named static, continuous, saccadic, stable, unstable and metastable.



An additional temporal form of balancing can occur during a footrace, a balancing form called "closing the gap." Closing-the gap balancing occurs in an episodic way around moments of challenge and/or passing. In the gap-closing form, a higher speed balances a spatial lead. (Recall the VOR, another disparate kind of balancing, where eye jerks balance head jerks.) The episodic balancing form is not represented by an iconic or symbolic form. Unlike iconic forms of balancing that hold to or maintain a condition or standard, closing-the-gap balancing is intentionally transformational.

A description of closing-the-gap balancing starts with the goal of the runner, namely, to run faster than the other runner from the starting signal to the finish line. At any moment, the one who has run faster (on average) is ahead. Suppose that he is ahead; he needs only to maintain his lead to win. The way things are going, it is sufficient for him to maintain his average speed. If he maintains his average speed and she maintains her average speed, his lead will increase. He will win by maintaining his average speed versus her average speed. She, in contrast, must increase her average speed to catch up and overtake him. This requires her to do things that he does not have to do. Chiefly she must close the ***gap*** that separates her moving position from his moving position. She must increase her average speed to overcome his average speed.

The gap is based on her experience of his body and also on her experience of the visual space between the bodies. Although both bodies are moving, the gap between them remains more or less fixed – or perhaps it is increasing a bit because of the speed differential that puts him in the lead. It is the gap, I suggest, that signals and identifies the necessity of what she must do. And she does do it, if she summons up ***extra effort*** and increases her speed. The gap identifies, indexes and encodes the extra effort she needs to speed up, to overtake him and to win the race.

As modeled by An Eye for Sharp Contrast, the gap between her body and his body is measured by muscles that control the focus of the Lens of the Eye. I suggest that she is looking at edges of his body and that there is a direct relationship between signals to her eye muscles that focus on edges and the distance to the object. I suggest that the extra muscular effort of her legs that is needed to close the gap is measured by muscles of her eyes. Her feeling of the need for extra effort is based on signals from her eye muscles. There is a foundation of muscle-to-muscle control that is foundational for any extra effort summoned up by a conscious personality.

Suppose that she summons up extra effort and increases her speed sufficiently so that the gap between the runners is no longer growing, if it was growing, but is instead shrinking. At first, it shrinks only a little, but then the extra effort takes hold and it begins to shrink faster. As the gap shrinks, she enters into a moment when she is challenging him. But now she is moving faster than he is. She is behind in space but ahead in speed. The balance is shifting. Her challenge shifts to him the requirement to summon up extra effort. If he does not summon up extra effort, and if there is sufficient time before they reach the finish line, the challenge will succeed and she will overtake him. If he does summon up extra effort, he may withstand the challenge, or his extra effort may not be enough to maintain the lead, or the race may enter into a see-saw form. Runners' needs for extra effort and their summoning up of extra effort may continue to the end of the race, even possibly leading to a new personal record for the event.

Summing up and extending the foregoing, a footrace is based on balancing forms that are grounded in symmetries as to persons, space and time. The symmetries and balancing forms have the purpose and effect of bringing into existence, however transient and ill-defined that existence, an additional balancing form that is based in action and that decides the outcome of the race. The additional balancing form appears as a closing-the-gap challenge by a runner who is behind in space but who is moving faster than the one who is ahead. There is possible ***extra effort*** that controls the outcome.

Extra effort is additional episodic effort on top of a high degree of constant effort. Added speed from extra effort can balance or even over-balance a spatial lead. Extra effort is a differential quantity of effort. It is identified, indexed and encoded by a visual gap between the leading runner and the challenger.

The episodic balancing form passes through a ***critical moment***, when the challenge either succeeds or fails or, perhaps, becomes the first of a series of critical moments. It is a critical moment of transformation that can occur as she who was behind becomes she who is ahead.

Principles discussed in connection with sports competitions also apply to courtroom proceedings. My practical experience includes professional participation in many such proceedings, chiefly in writing briefs and other formal presentations to judges. Most of my professional work has been in civil litigation, where contestants are private parties engaging in competitive efforts to persuade judges and juries. Such proceedings incorporate principles of symmetry that are simpler than those applied in criminal proceedings or in disputes between an individual and a government agency such as the Internal Revenue Service.

Comparison of courtroom proceedings in civil litigation with sports competitions reveals both important resemblances and key distinctions both as to general character and as revealed through analysis based on balancing principles developed above. Overall resemblances include the highly important "winning for the sake of winning." Alternatively, lawyers, like athletes, hate to lose. However, lawyers often have an alternative to the victory/defeat, namely settlement. Unlike victory/defeat, settlement typically leaves everyone dis-satisfied. The cost of avoiding painful defeat is to give up glorious victory.

Another distinction between the two domains is that legal contests have consequences that are weightier than those of sports contests, often involving accusations of dishonesty or financial stakes of serious importance to the parties. Weight is added through implicit involvement of a "society" that needs to enforce principles of legal authority discussed below. Respect for others and sincerity in expression are significant values in courtroom proceedings, while sometimes neglected on the fields of sports. Formality of dress and demeanor is the style of courtrooms while informality is more sporting. "Gamesmanship" that might be praised in competitive sports is officially condemned in the courtroom, at least as far as the litigants are concerned. In courtrooms, "gamesmanship" is the exclusive privilege of judges, who exercise freedom with regal authority, in contrast to beleaguered baseball umpires and other game officials who are bound by strict duties and who must endure squabbling objections.

Courtroom proceedings occur within an historical context. There is a body of writings, discussed below, that are supposed to guide if not determine resolution of the current case. A declared purpose of proceedings is to turn the present dispute into a past dispute by following the writings. Novel ideas in litigation are rare and are even more rarely welcomed. In contrast, each sports events is independent and fresh. In sports, there is nothing binding about history or statistics. A previously unknown team or contestant is not given a handicap because of novelty.

Analytically, legal proceedings resemble sports competitions in providing institutional means for resolution of strife by means of selections made during courses of action that are supposed to be "fair," that lead to definite outcomes and that involve winning and prizes. A jury trial has a critical moment of decision, namely, when the jury is deliberating in the jury room. All activity of a trial is aimed at influencing that critical moment. A trial lawyer thinks about jury deliberations during the initial interview with a prospective client.

Popular imagery dramatizes courtroom proceedings through scripted critical moments that resemble excerpts from the big game on the evening news. In actual practice, legal proceedings are tedious and prolonged. Critical moments are stretched out and dissected until everyone is tired of it. When everyone is tired of it, a decision is close at hand. If sports competitions were intentionally boring like legal proceedings, the stadiums would be empty.

From the perspective of context, both domains, sports and courts, are constructed to further social values. Sports competitions appear in all societies and are self-perpetuating, being played and watched for their own sake by large fractions of the populace. In actual life, sports teams become civic institutions. Courts are established by all governments to enforce their mandates and prohibitions; to protect personal rights, property possessions and transactional integrity; and to resolve disputes involving governments, individuals and/or private organizations.

A "court" is a place where a judge presides; often the judge is called "the court." In the court, the judge is in absolute control and has an armed bailiff ready to arrest and imprison offenders on instructions from the judge. Another way the judge controls events is to send orders to the sheriff. The sheriff will obey a judge's order, e.g., the sheriff will use armed force, if necessary, to evict a tenant residing in an apartment when the owner has obtained a suitable court order based on the failure of the tenant to pay rent. Action by the sheriff is the court's equivalent of muscular movements of an organism. The territorial area in which the sheriff will perform such acts of enforcement according to the judge's orders defines the court's ***jurisdiction***. Typically, judges in one court will enforce orders written by judges in other courts, but questions can arise.

Both sports and courts employ symmetrical and invariant forms of contest to control and resolve strife. In judicial proceedings, parties and/or attorneys — the competing "plaintiff" and "defendant" — have an equal status before the court. At least, such equality is practiced to the extent feasible under the circumstances. In a courtroom, the elevated judge's bench is the central focus. Space before the bench has two halves with equal furniture and furnishings provided to plaintiff and defendant and their lawyers. The witness chair and nearby jury box create an asymmetry which is usually resolved according to local tradition, e.g., plaintiff is closer to witness and jury box. Procedures apply the same to all parties and remain invariant for long periods; occasional changes are usually small, with infrequent major revisions.

Civil trials in courtrooms provide voluminous case studies of actual resolutions of strife through contests and outcomes that have winners and losers. (Other methods of resolution lead, e.g., to settlements.) Of importance in legal contests are ***written rules of law***, providing intellectual content that is absent in sports contests. Chief written rules of law are constitutions, statutes passed by legislatures and precedential case opinions of courts of appeal. When trial judges and appellate judges write about current cases, they do so in terms of written rules of law.

Written rules of law occupy an imaginary metaphysical domain that resembles the metaphysical domains of geometry, platonic Ideas and Laws of Physics discussed previously. I use the phrase "jurisprudential law" to denote the legal metaphysical domain. Principles of symmetry and invariance are of paramount importance in jurisprudential law, as in other such domains. Constructions put together in such metaphysical domains are supposed to control actual lives.

It is undeniable that judges do control actual lives through powers of the state. For example, if the court enters a money judgment in favor of plaintiff and against defendant and the court issues orders to the sheriff, the sheriff will deliver instructions to bank officers to transfer money from defendant's bank account to the sheriff's bank account; and bank officers will comply with such instructions. Later, the sheriff will deliver the money to plaintiff. There, it's done and it's over.

A chief question (encountered in other guises in previous discussions) is the connection, if any, between metaphysical constructions of jurisprudential law and actual exercises of state power. One possibility is that decisions by courts are based on reasoned applications to individual cases of invariant and symmetrical principles of jurisprudential law. There are widespread beliefs that such "rational" operations and applications occur naturally in legal practice. (In *Law and the Modern Mind*, "The Basic Myth," Frank disparages such beliefs.) Another possible view is that claims about such rational operations are fabrications that try to camouflage the hegemony of a ruling class. According to this view, it is asymmetrical injustice that is invariant, if anything is. A third view is that court decisions are arbitrary, lacking symmetry or invariance despite illusions or pretenses to the contrary; rather, decisions are based on political connections of judicial appointees or prejudices of jurors. Supposedly, the decider aims for a particular result that suits such connections or prejudices and then constructs a statement to justify the desired result. Such divergent possibilities, views and beliefs are topics of academic discourse.

My own views are rather different. Yes, many specific cases support each of the stated views. However, what actually happens often has a more practical character. Satisfactory results are generally achieved when deciders ***follow the forms*** and ***the forms fit the task***. Often the forms authorize deciders to exercise freedom. However, such forms are usually not based on invariant and symmetrical principles. In practice, they often don't fit the task. Sometimes deciders don't follow the forms.

The task of a judge or jury in a lawsuit is to decide questions that are implicit in a dispute. Which side is right? If plaintiff is right, how much must defendant pay to plaintiff to make things equal, more or less? American jurisprudence divides legal questions into classes according to the person who decides the questions. During a civil trial, certain questions, called ***questions of fact***, are decided by the jury. Other questions, called ***questions of law***, are decided by the trial court judge. After the trial, the losing party may appeal the judgment. A principle of appellate law is that the jury's decisions as to questions of fact will be taken as truth. Taking the jury's decisions as "true," the appeal court will try to make the jury's decisions justify the judgment. The appeal court will be more critical of the trial court judge's decisions on questions of law. Often, the appeal court will substitute its decision for that of the trial court judge. Another class of trial court decisions, called ***discretionary questions***, is treated more respectfully by appeal courts. As might be expected, some cases turn on the classification of questions. As exemplars: the amount of money compensation awarded by a jury is a question of fact within a broad range; whether a party has a right to have a claim decided by a jury is a question of law; daily scheduling of the trial is a matter of trial court discretion.

In an actual jury trial, the jurors are the focus of attempts at persuasion. The jury's moment of decision occurs in the jury room close to the end of the trial. Most of the time during a trial is spent in obtaining formal testimony through lawyers' interrogation or examination of parties and witnesses and in dealing with physical evidence, e.g., documents, data sets and audio-visual presentations. After completion of testimony and evidence, the lawyers make ***closing arguments***, which are major efforts at persuasion. First the plaintiff's lawyer argues to the jury, then the defendant's lawyer argues to the jury, then the plaintiff's lawyer gets to make the last argument. After the arguments, the trial court judge ***instructs*** the jury, telling the jury the principles of jurisprudential law that should control their decisions. The instructions are set forth in formal ***jury instructions***. The jury instructions include ***jury verdict forms*** that set forth questions to the jury. When lawyers make closing arguments, they know the jury instructions and jury verdict forms that will be provided to the jury and they often quote from and argue from the text of the jury instructions and verdict forms. The focus here is on the decisional process of the jury that is influenced by jury instructions and verdict forms and by lawyer's arguments to the jury.

I suggest that decisions made by both judges and jurors are designed to lead to actual results. Such decisions have specific forms that have been shaped by needs to perform final and completing tasks, e.g., so that results can be turned into an unambiguous order or judgment that is enforceable by staff working in the sheriff's office, without need of legal interpretation. All the complexities of jurisprudential law must finally be reduced to simple acts. Either plaintiff wins an award of damages for a specific dollar amount or the case is dismissed. No other final result is possible, at least in a narrow view that sees only results. Whatever the result, the dispute reaches a stage of completion and resolution and neither party can question the result or return to the dispute, except through an appeal or other formal challenge that has explicit or implicit deadlines and limits.

In other words, I suggest that certain legal forms provide important intermediary functions. Such legal forms connect the metaphysical domain of jurisprudential law with the enforcement arm of the sheriff's office. At critical moments in proceedings, judges and jurors use legal forms to answer questions and reach results. Each such proceeding reduces the ambiguity and moves the case towards final resolution. A legal form provides a tool for judges and jurors to perform tasks assigned to them. When they do so, they ***follow the form***. The understanding is that if they follow the form, subsequent events will go smoothly and the matter can be closed and will stay closed. If judges or jurors want to reach a particular result, the form tells them whether they can do so in good conscience. Judges and jurors generally find that legal forms satisfy their desires and consciences. Legal forms are designed to provide satisfaction for deciders. What satisfies deciders, at least deciders in court, is actually reaching a decision and concluding the matter. Then, it's time to go home while victors celebrate and losers grieve.

In order to achieve intermediary functions, some terms in legal forms are highly specific and other terms are quite vague. Vague or ***ambiguous*** terms in legal forms, e.g., "reasonable under the circumstances," authorize judges and juries to exercise freedom in turning metaphysical principles into judgments and orders. This essay concludes with a discussion of use of legal ambiguity as an exemplar of operational freedom that is exercised by courts.

Often, courts use ambiguous forms at an earlier stage in proceedings and unambiguous forms at a later stage of proceedings. At the earlier stage of proceedings, a judge make decisions with sensitivity to multiple influences and multiple possible outcomes. At the last stage of proceedings, the sheriff carries out simple and clear instructions. Such a course of action resembles those discussed earlier where delicate decisions turn into strong movements.

Judges and jurors also follow forms, based on symmetry, that call on them to be personally indifferent to the outcome of the case and to be insulated from unauthorized influences. I suggest that judges and juries follow such forms because following forms is the essence of institutional activity. Such a suggestion can be supported by many examples, beginning with ancient religious rituals and continuing through sports, music and science. Institutions operate through forms; and institutions discipline, exclude or punish persons who fail to follow such forms. Persons who follow institutional forms are performing self-perpetuating behaviors – doing it for the sake of doing it – behaviors that are called "duties" or "traditions" in institutions.

Legal forms of various kinds are set forth in writings published by specialty business firms with venerable names. Published sets of legal forms have huge sizes and law libraries have racks of them. Law students learn how to find and use legal forms in law school courses on legal research. Attorneys have duties of lifelong education to keep up with changes in legal forms. Legal forms are to a lawyer what lumber and hardware are to a carpenter, providing means and models for ways to put together substantive facts and principles and to make a functional object through construction.

A chief legal form used during critical moments in trials is the ***jury instruction***, introduced above. After presentation of evidence and lawyers' arguments to the jury, the trial judge provides the jury with a statement of principles of law that the jury is to use in reaching a decision. Typically the judge reads aloud a set of such principles – the jury instructions – to the jury in a ritual session of proceedings in court. Then the jury retires to the jury room for private discussions and the moment of decision. Sometimes jury instructions and verdict forms are printed in a booklet that jurors take with them into the jury room.

Jury instructions and accompanying verdict forms are, in my view, pivotal forms in trial proceedings. They are actual means for turning evidence and argument into judgments. Often lawyers quote from them in the climactic and all-important closing arguments. A lawyer begins preparing closing arguments in his or her mind the moment the case is first considered. The lawyer acquires evidence before the trial and presents it during the trial for the purpose of being used in closing argument.

The judge's decisions concerning jury instructions, like all judicial decisions, are subject to conflicting and concurrent influences that are generated and cultivated by the lawyers for purposes of contest. Sometimes, a lawyer with a losing case will try to confuse proceedings and cause the judge or the other side to stumble and commit error that will persuade the court of appeal to reverse. The formulation of jury instructions is within the power of the trial judge and his or her decisions regarding jury instructions are given a permissive review by a court of appeal, with a standard of review that is between review of right to jury questions (strict) and review of scheduling questions (loose).

Jury instructions and verdict forms often include ***programs for decision*** for the jury. In 1995, for example, football star and entertainment celebrity O. J. Simpson was acquitted of criminal charges that he murdered his estranged wife, Nicole Brown Simpson, and her friend, Ron Goldman. Thereafter, Goldman's parents sued Simpson in civil court, seeking money as compensation for damages they claimed that Simpson had inflicted on them by killing their son. Their claims were not affected by Simpson's acquittal. Chiefly, the State of California had been required to prove Simpson's guilt "beyond a reasonable doubt" in criminal proceedings but, in civil proceedings, Goldman's parents only had to prove that it was "more likely than not" that Simpson had killed their son. This is the "preponderance of the evidence test," a ***balancing*** test.

In the jury room, the jury followed a verdict form that had a series of questions in a structure that resembled a flow-chart in computer programming:

"Question No. 1: Do you find by a preponderance of the evidence that defendant Simpson wilfully and wrongfully caused the death of Ronald Goldman? (Answer) Yes. …

Question No. 8: We award damages against defendant Simpson and in favor of plaintiffs: (Answer) $8.5 million."

The preponderance of the evidence test is stated in CACI 200. "CACI" refers to forms of Civil Jury Instructions published by an authoritative State agency, the Judicial Council of California.

> A party must persuade you, by the evidence presented in court, that what he or she is required to prove is more likely to be true than not true. This is referred to as "the burden of proof."
>
> After weighing all of the evidence, if you cannot decide that something is more likely to be true than not true, you must conclude that the party did not prove it. You should consider all the evidence, no matter which party produced the evidence.
>
> In criminal trials, the prosecution must prove that the defendant is guilty beyond a reasonable doubt. But in civil trials, such as this one, the party who is required to prove something need prove only that it is more likely to be true than not true.

"More likely than not" implies a balancing between "likely" and "not likely," with a finding of greater weight on the "likely" side. It need be only a little bit weightier, like 51% to 49%, but it has to be more than 50-50.

Specific examples of express balancing are found in CACI (emphases added).

Where plaintiff claims having suffered harm from using a product manufactured by defendant, the jury may be instructed: "In determining whether defendant used reasonable care, you should ***balance*** what defendant knew or should have known about the likelihood and severity of potential harm from the product against the burden of taking safety measures to reduce or avoid the harm." (CACI 1221.)

If plaintiff claims harm from a dangerous condition on public property maintained by a governmental entity, the jury may be instructed: "In deciding whether defendant should have discovered the dangerous condition, you may consider whether it had a reasonable inspection system and whether a reasonable system would have revealed the dangerous condition. In determining whether an inspection system is reasonable, you may consider the practicality and cost of the system and ***balance*** those factors against the likelihood and seriousness of the potential danger if no such system existed." (CACI 1104.)

Where discharged plaintiff employee and defendant employer had an employment agreement that employee would not be discharged except for "good cause," a possible instruction states: "Good cause exists when an employer's decision to discharge an employee is made in good faith and based on a fair and honest reason. Good cause does not exist if the employer's reasons for the discharge are trivial, arbitrary, inconsistent with usual practices, or unrelated to business needs or goals or if the stated reasons conceal the employer's true reasons. In deciding whether defendant had good cause to discharge plaintiff, you must ***balance*** defendant's interest in operating the business efficiently and profitably against the interest of plaintiff in maintaining employment." (CACI 2404.)

As the foregoing instructions demonstrate, jurors may be called upon to balance different categories that have no clear basis for comparison, e.g., balancing "likelihood and severity of potential harm" from a dangerous product against "the burden of taking safety measures." Such ***disparate subject matters*** are supposed to be balanced according to lines of cases that trace back to United States v. Carroll Towing Co. 159 F.2d 169 (2d. Cir. 1947) where Judge Learned Hand stated a "calculus of negligence."

There are occasional cases where "risks of harms" and "ways to avoid harm" can be "balanced" using monetary estimates; but mostly, meanings are winked at, modified or distorted to suit the litigation goals of the parties or to justify a decision made by a court or a jury. Techniques include presentation of confusing or conflicting evidence from hired "scientific experts." Whatever decision the jury reaches will find support in the record of such evidence. It may happen, in actual life, that neither side is credible and that the decision is made for other reasons. Fitting the form may be crude, clumsy and forced. Imperfect fits are common in civil litigation. Such crudeness and clumsiness allow many cases to fit a form, even if imperfectly. Courts of appeal affirm the result regardless of defects so long as there is an appearance of justification. There, it's done and it's over.

Attempts to balance disparate matters do not fit the nature of a mathematical calculus, which deals with continuously variable quantities connected by equals signs. I suggest, rather, that legal balancing rules are statements of saccadic and shimmering balancing that require a wider perspective than mathematical formulations allow. Disparate kinds of influences have to be accommodated. Put into practice, such rules allow a manufacturer to sell a product like a chainsaw that is inherently dangerous if there are safety devices that frustrate children and warning labels. The defense is a practical one: there's nothing more that can be done to protect the public short of withdrawing the product from the market or making it prohibitively complicated or expensive. To support the defense, large bright red warning labels are advisable.

Balancing tests are generalized when the jury is called upon to ***weigh*** or balance a number of disparate subject matters. In a case claiming a defective design of a consumer product, for example, the jury may be instructed that if plaintiff proves that she was harmed because of the risky design of defendant's product, the jury should find in favor of the plaintiff:

"unless defendant proves that the benefits of the design outweigh the risks of the design. In deciding whether the benefits outweigh the risks, you should consider the following:

(a) The gravity of the potential harm resulting from the use of the product;

(b) The likelihood that this harm would occur;

(c) The feasibility of an alternative safer design at the time of manufacture;

(d) The cost of an alternative design; and

(e) The disadvantages of an alternative design."

Such a weighing does not merely balance one disparate subject matter against a second such matter. Rather, many subject matters are thrown onto the scales.

Using terminology introduced above, balancing forms used in footraces can be modeled using a continuous activation; models of balancing forms used in civil trials require saccadic and shimmering activations. The gap in a footrace, a spatial quantity, becomes a formal ***distinction*** (or a structure of distinctions) in jurisprudential law. That is, a gap in a footrace is a difference in a spatial quantity that identifies, indexes and encodes the need for extra effort to change an outcome. A legal distinction, in contrast, states a difference in kind that identifies, indexes and encodes the content that is needed for different outcomes in two comparable civil cases. Plaintiff wins in case 1 but defendant wins in similar case 2: a distinction between the two cases justifies the different outcomes. I suggest that muscular forms of balancing in a footrace have counterparts in legal forms that are chiefly conceptual.

The gap in a footrace defines a focal space that separates two runners in an athletic domain; a distinction in legal cases identifies facts that are causes for different treatment. Such a space and such a distinction may have similar decisive importance in corresponding critical moments.

Use of distinctions in legal forms is illustrated by the development of protections for workers injured during the course of employment. Such injuries are frequent because many kinds of employment are dangerous. Changing social and political attitudes have led to development of laws that impose on employers certain responsibilities for injured workers.

According to scholars, the ancient Babylonian Code of Hammurabi declared that employers were liable for any injury that might befall a worker in the course of his labor. (Herlick, § 1.01.) Apparently, slavery was rare in ancient Babylonia and employment was mostly contractual. Employment relations in subsequent civilizations were based on slavery, feudalism, indenture and paternalism; whatever their defects, such relationships made an employer responsible for care of injured workers. The Industrial Revolution changed such relations. It also led to enormous increases in worker injuries.

As stated in Friedman, *A History of American Law* (1973) at 262-263:

> The explosion of tort law, and negligence in particular, must be entirely attributed to the age of engines and machines. … The machines and tools of modern man…blindly cripple and maim their servants. From about 1840 on, one specific machine, the railroad locomotive, generated, on its own steam (so to speak), more tort law than any other in the 19th century. The railroad engine swept like a great roaring bull through the countryside, carrying out an economic and social revolution; but it exacted a toll of thousands, injured and dead.
>
> The existing law of tort was not prepared to bear the burden of these accidents. … The law developed in a way which the power-holders of the day considered socially desirable. This way, in brief, was to frame rules friendly to the growth of young businesses; or at least rules the judges thought would foster such growth. … The most famous (or infamous) new doctrine was the fellow-servant rule. This was the rule that one servant (employee) could not sue his master (employer) for injuries caused by the negligence of another employee. … Chief Justice Lemuel Shaw of Massachusetts wrote … that the workman who takes on a dangerous job must be held to have assumed the ordinary risks of that job. In theory, the wage rate included an adjustment for the added danger. Since that was so, the risk must be left on the person who had, for a price, voluntarily assumed it. The injured workman was thus thrown back on his own resources or, if he had none, to the tender mercies of the poor laws.

The fellow-servant rule introduced a distinction into the developing law of negligence and also into the law of agency. "In the law of agency, the principal [employer] is generally liable for negligent acts of his agent [fellow-servant]. … But this general rule was never extended to the factory and to railroad yard workers." (263, emendations added.)

"To keep the workers reasonably content, European legislatures enacted workers' compensation laws in the late 1880's. It took about a generation for the idea to span the Atlantic. California was one of the first states to enact a workers' compensation law." (Herlick, § 1.01.)

Workers' compensation systems amount to a re-balancing of the legal system for injured workers. The distinct treatment of such workers was institutionalized. Through legislative enactments, mandates are imposed on all employers and on their employees. Employers are required to contribute money to a fund in amounts proportional to their payrolls and rate of injuries and the fund pays for treatment of injured workers. The fund is managed like an insurance company. Workers are entitled to treatment for injuries sustained during the course of employment regardless of fault, whether the employer's fault, a fellow-worker's fault or their own fault. It is a no-fault system unlike the traditional negligence system where a person could not recover for injuries sustained through his or her own fault. As part of the re-balancing, workers lose claims and rights they would have in court proceedings, such as claims for pain and suffering and the right to a jury trial. Injured workers' claims are excluded from regular courts. Workers' compensation proceedings are quicker than court proceedings and are conducted by special tribunals that may be accused of institutional biases. Workers may lose some or all control over their medical care and rehabilitation. Such re-balancing amounts to an enforced bargain, where each side gives something and gets something.

To sum up, I suggest that balancing forms are used throughout legal proceedings, even appearing in symbols of justice and of the legal profession. Legal balancing forms and balancing forms of sports competitions grow out of a common ground in actual life. Such forms incorporate symmetry and invariance; also, shifting asymmetries are of focal importance. Balancing forms combine a symmetrized spatial character with an episodic temporal character.

The final construction develops previously-discussed principles into a view of jurisprudential law. Jurisprudential law is stated in constitutions, statutes and court decisions. Jurisprudential law states fixed principles that are supposed to control legal proceedings in courtrooms. Of perhaps even greater consequence, jurisprudential law states fixed principles that are supposed to control actual lives of persons in society.

Jurisprudential law can both be assimilated to and also distinguished from scientific law.

In my view, all law – whether scientific, jurisprudential or moral – has a primal form that states what a body must do and/or what a body must not do. "Thou shalt" and "thou shalt not" are formalizations of parental instructions. As discussed below, Jerome Frank stated something similar in *Law and the Modern Mind*. Scientific law applies "shalt" and "shalt not" to material bodies. In jurisprudential law, the body is called a person. To use such words in parallel statements: the law of gravity states that a material body that is dropped from a height must fall according to a certain formula; and the Vehicle Code states that a person must not drive a car through a red traffic light and if such an act is performed, a certain penalty will be imposed.

In other words, the primal form of a law is a mandatory or prohibitory action statement applicable to a class of activities of a class of bodies. Pursuant to the form, the law applies to all such designated activities of all bodies within the class in a rigid, symmetrical and invariant way. Such a form is often useful but there are many situations where the actual case does not fit easily into the form. Jurisprudential law has developed flexible adaptations to deal with such situations.

Investigation into jurisprudential law starts with three basic forms of legal reasoning that have been followed in Western Civilization since days of the Roman Empire, all based on notions about the origin of law, namely: (1) jurisprudential law is inherent in things and eternal, as declared by a deity or discovered scientifically — called the ***natural law*** theory;
(2) jurisprudential law is the will of the ruling Sovereign, declared and enforced for His, Her or Its purposes, however transient — called the ***positive law*** theory; and (3) jurisprudential law is a formalized expression of traditions established in a community and/or from a course of dealings between parties — called the ***customary law*** theory.

See D. J. Boorstin, *The Mysterious Science of the Law: an Essay on Blackstone's Commentaries* (1941, 1996) as to natural law; H. L. A. Hart, *The Concept of Law* (1961), chiefly propounding positive law; and Lon L. Fuller, *Anatomy of the Law* (1968), which discusses customary law.

The most powerful statement of natural law was written by Thomas Jefferson in the American Declaration of Independence: "We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness." Jefferson (1743-1826) got many of his ideas from Blackstone (1723-1780). (Boorstin.) In recent times, natural law theory has been used to expand concepts of human and civil rights.

A simple example of positive law is the law of taxes. Whether imposed by a tyrant or by a popular Congress of the United States, taxes are painful and many persons would not pay them but for even greater pain that is threatened for failure to pay. A Sovereign can impose taxes in one form or another or in a range of rates according to His, Her or Its financial needs and political considerations: the instrumentalities of taxation are highly adaptable to practicalities of situations. Neither eternal principles nor community traditions are much of an impediment to a Sovereign's determination to tax. A threat of insurrection or mass refusal is probably the most potent curb.

Major examples of customary law start with the ***law merchant*** that enabled traders in far-flung ports to deal with one another. Chiefly, sailing ships were risky vehicles for precious metals or money. It was much safer and easier to take a piece of paper that entitled the identified bearer to get or deposit money, so long as counterparts in such transactions were reliable. In the medieval era, especially in ports around the Mediterranean Sea and the cold but cozy Baltic Sea, customary forms of dealing arose to make such documentary transactions easy and convenient, with appropriate charges for services. Handling such transactions for customers became activity of trading companies, moneylenders, moneychangers and operators of markets and exchanges. Respected neutral members of the community resolved disputes.

With the advent of railroads in the nineteenth century, development of forms of the law merchant in the United States blossomed to deal with the enlarged geographic reach of trading, e.g., forms used in freight forwarding and credit arrangements. The need for approved and mandatory forms led to legislative enactment of State codes of laws regulating Sales. Private organizations sponsored new developments, of which perhaps the most successful is the Uniform Commercial Code that facilitates interstate commerce and that has been adopted, with variations, by all the States of the United States. (Gilmore.) Customary laws became strict rules, along with new standards, e.g., those stated in warranties that accompany consumer products.

In addition to the three traditional theories of jurisprudence based on the supposed origin of law (natural, positive and customary theories), there is a fourth approach that has, as a practical matter, superseded them all, borrowing authority from such traditional theories to support its utilitarian purposes. The fourth approach has no simple name but one label is the ***social interests approach***. According to a social interests formulation, the law is an instrument that is applied to achieve certain social interests, goals or purposes. The social interests approach focuses on goals and purposes rather than on origins. For example, the purposes of the Uniform Commercial Code are stated as part of the Code: "(a) to simplify, clarify and modernize the law governing commercial transactions; (b) to permit the continued expansion of commercial practices through custom, usage and agreement of the parties; (c) to make uniform the law among the various jurisdictions." (UCC § 1-102.) Accordingly, a State court faced with a novel kind of problem will review and tend to apply rules that have been adopted by a consensus of other States. Courts enforce a social and commercial interest in having uniform rules across the nation.

The social interests approach developed during the late 19th and early 20th centuries. It is often attributed to Oliver Wendell Holmes, Jr. (1841-1935). Holmes fought as a junior officer in the American Civil War, wrote major Supreme Court opinions and welcomed newly-elected President Franklin D. Roosevelt to Washington in 1933. On the opening page of *The Common Law* (1881), Holmes famously announced the new era of jurisprudence (emphasis added):

> The life of the law has not been logic: it has been experience. The felt necessities of the time, the prevalent moral and political theories, intuitions of public policy, avowed or unconscious, even the prejudices which judges share with their fellow-men, have had a good deal more to do than the syllogism in determining the rules by which men should be governed. The law embodies the story of a nation's development through many centuries, and it cannot be dealt with as if it contained only the axioms and corollaries of a book of mathematics. In order to know what it is, we must know what it has been, and what it tends to become. We must alternately consult history and existing theories of legislation. ***But the most difficult labor will be to understand the combination of the two into new products at every stage.***

In *The Path of the Law* (1897), Holmes wrote (emphasis added):

> Take the fundamental question, What constitutes the law? You will find some text writers telling you that it is something different from what is decided by the courts of Massachusetts or England, that it is a system of reason, that it is a deduction from principles of ethics or admitted axioms or what not, which may or may not coincide with the decisions. But if we take the view of our friend the bad man we shall find that he does not care two straws for the axioms or deductions, but that he does want to know what the Massachusetts or English courts are likely to do in fact. I am much of this mind. ***The prophecies of what the courts will do in fact, and nothing more pretentious, are what I mean by the law***.

From my perspective, Holmes was declaring an ***actual jurisprudence*** that is based on actual decisions, practices and procedures of courts and other institutions. During the 1930's, the social interests approach was called ***Legal Realism***. Jerome Frank (1889-1957), a leading legal realist, served as Chairman of the Securities and Exchange Commission and as a Judge on the Second Circuit Court of Appeals; he also wrote *Law and the Modern Mind* introduced above, which extolled the practical reasoning of Holmes. Frank challenged the hegemony of traditional legal theories, using polemical labels such as "the basic myth," "legal fundamentalism" and "mechanical jurisprudence." Please compare to "platonic science" herein.

Actual jurisprudence focuses on selections and other exercises of freedom by judges and juries. However, written laws are often stated in traditional formulations of mandates or prohibitions that appear to apply to classes in invariant and symmetrical ways. Such formulations are not always suitable for the personalized decisions that actual disputes require. Various methods are used to modify invariant formulations so as to accommodate and allow for personalized decisions, including ***methods of verbal ambiguity***. An ambiguous verbal term can be interpreted and an interpretation can take into account various considerations that can lead to various results. Using methods of ambiguity, judges and juries exercise freedom in deciding disputes. Modern formulations of laws often incorporate such exercises of freedom expressly, e.g., in balancing procedures used by a judge in deciding whether to issue a preliminary injunction.

Such freedom was described in detail by Gilmore & Black in *The Law of Admiralty* (2d ed. 1975), § 10-20 in connection with a particular legal question that is somewhat complex. Some background provides context. United States Congresses enacted and Presidents signed bills dealing with commercial shipping that, in the aggregate, are called the Limitation Act. Included in the Limitation Act are two key phrases that illustrate ambiguity, namely, "privity or knowledge" and "design or neglect." Under the Act (and ignoring everything but this issue), a shipowner whose vessel is involved in a catastrophe can limit his liability to the value of the vessel and be exonerated from further liability, e.g., as to claims from owners of lost cargo. (Claims by injured seamen are more complex.) In effect, the shipowner can legally say: "take the wreck, I'm through" – unless his role in the catastrophe is characterized by "privity or knowledge" or if there was "design or neglect" on his part; and, if so, then there is ***no*** limitation and ***no*** exoneration. Such rules were first established when seafaring was routinely hazardous and were meant to free a shipowner from claims arising from catastrophic loss if he attended to matters involving the ship in the ordinary course of business. The ambiguities in enforcement of the enacted laws ("statutes") are clearly identified in the following passage by Yale Law School professors with expertise in legal history and jurisprudence (emphases added, reference omitted).

> "Privity or knowledge" and "design or neglect" are phrases devoid of meaning. They are ***empty containers into which the courts are free to pour whatever content they will***. The statutes might quite as well say that the owner is entitled to exoneration from liability or to limitation of liability if, on all the equities of the case, the court feels that the result is desirable; otherwise not. Since, in the infinite range of factual situations no two cases will ever precisely duplicate each other, no judge with the slightest flair for the lawyer's craft of distinguishing cases need ever be bound by precedent: "privity like knowledge," the Supreme Court has remarked, "turns on the facts of particular cases."
>
> Judicial attitudes shape the meaning of such catch-word phrases for successive generations. In the heyday of the Limitation Act it seemed as hard to pin "privity or knowledge" on the petitioning shipowner as it is thought to be for the camel to pass through the needle's eye. To the extent that in our own or a subsequent generation the philosophy of the Limitation Act is found less appealing, that attitude will be implemented by a relaxed attitude towards what constitutes "privity or knowledge" or "design or neglect." ***The Act, like an accordion, can be stretched or narrowed at will***.

According to the authors, "the courts" are able to play with laws in the style of a musician, re-writing tunes that control outcomes. Such exercises of freedom by courts are stated in terms of targets that may be "hard to pin" until a "relaxed attitude" appears; in terms of "empty containers" into which courts "are free to pour whatever content they will;" and by muscle-like movements that can "stretch and narrow at will" legal liabilities and exonerations.

Here at last we have found a "free will" that connects to actual life. The "will" of the courts clearly denotes the freedom that judges exercise, along with the power that they obtain through the legal system. Similar kinds of freedom are given to juries, with narrower decisions and indirect powers. Such kinds of freedom appear to be subject to analysis based on episodic forms of balancing that can be modeled and mimicked using new technologies. Kits of parts suggest further developments. However, such anticipated projects reach too far beyond limitations of platonic science for purposes of this essay; they are, therefore, left for subsequent constructions.

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