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

by Robert Kovsky

"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 analysis of forms of "platonic science" that were invented in ancient Greece and that have developed into modern physics. Static and quasi-static forms are suited for placid equilibrium conditions and relaxation processes. Linear forms, abstracted from geometrical space, impose rigidity and continuity. Such spatial forms fail to describe muscular movements of animals that have actual life. Limitations of platonic science are overcome by means of new forms with the character of time, e.g., a form of a beat and saccadic (jumpy) forms. New technologies of action and freedom generate and control temporal forms in proposed device models of brains. Some temporal forms have critical moments of transformation, e.g., a moment of overtaking during a footrace or a jury's moment of decision during a trial in court.

<u>Condensed outline</u>

1. A solution to free-will puzzles starts with muscular movements of actual life.
2. Nietzsche's "will to power" shows the fallacious character of metaphysical constructions that fail to connect to actual life.
3. In metaphysical constructions that were developed by ancient Greeks through "platonic science," an imaginary domain is occupied by mental objects called "Ideas" that are impersonal and eternal, that have the character of geometrical space and that are supposed to control actual lives of persons.
4. Modern versions of platonic science construct imaginary domains in which passive bodies undergo quasi-static changes according to eternal impersonal spatial forms called "Laws of Physics" that supposedly control everything.
5. Actual life does not fit into spatial forms of platonic science. In new constructions, muscular movements of actual life are modeled by temporal forms, including forms that control race contests in sports arenas and jury trials in courtrooms. Outcomes of such events turn on personal efforts and personal decisions that occur during transformational critical moments.

[Not included in 2011 draft.]

6. In contrast to computers that use static forms and embody spatial principles of platonic science, timing devices and Quad Nets are new technologies that use temporal forms and embody principles of action and freedom.

Detailed outline

1. A solution to free-will puzzles starts with muscular movements of actual life.
   a. Free-will puzzles vs. freedom in actual life.
   b. Actual life begins with infantile repetition of muscular movements.
   c. Infantile repetition develops into scientific invariance.
   d. In contrast to empty concepts of "will" and "free will," science and technology have had good luck with metaphysical constructions.

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

3. In metaphysical constructions that were developed by ancient Greeks through "platonic science," an imaginary domain is occupied by mental objects called "Ideas" that are impersonal and eternal, that have the character 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 symmetrized rigidity.
   d. Platonic constructions have the character of geometrical space.

4. Modern versions of platonic science construct imaginary domains in which passive bodies undergo quasi-static changes according to eternal impersonal spatial forms called "Laws of Physics" that supposedly control everything.
   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. Spatialization of time fits the primal linear form of platonic science.
   d. Thermodynamics is based on "equilibrium" that excludes multiple possibilities, that imposes continuity and that leads to linear forms.
   e. "Quasi-static 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.
   f. Laws of Physics fail to describe or control discontinuous transformations of water vapor into individual crystalline snowflakes.

5. Actual life does not fit into spatial forms of platonic science. In new constructions, muscular movements of actual life are modeled by temporal forms, including forms that control race contests in sports arenas and jury trials in courtrooms. Outcomes of such events turn on personal efforts and personal decisions that occur during transformational critical moments.

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

   b. The beat generates muscle-like activation in device designs that are part of proposed new technologies.

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

   d. Sports contests and civil trials illustrate partial adaptations of strife to symmetry and invariance, leading to balancing forms that climax in critical moments of personal effort and overtaking during footraces and in critical moments of personal decision by judges and juries.

[Not included in 2011 draft]

6. In contrast to computers that use static forms and embody spatial principles of platonic science, timing devices and Quad Nets are new technologies that use temporal forms and embody principles of action and freedom.

   a. Timing device designs of sensory-motor modules for balancing, following and focusing are based on generation of multiple possible signals that change into a single actual signal.

   b. In designs for proposed engineered organisms, sensory-motor modules produce muscular movements and generate sensory signals; drive modules start, stop and coordinate sensory-motor operations; additional modules that organize such movements, signals and drives generate imagery that signals, indexes and encodes their activities.

   c. Free-will puzzles confuse the commencement of a process of selection with the selection itself – which may be chiefly muscular – and confuse a selection with imagery generated during the selection.

   d. Interconnected Quad Net devices generate cycles of critical moments and decision jumps so as to arouse and sustain Shimmering Sensitivity within a flickering body of movement, imagery, action and freedom.

1. A solution to free-will puzzles starts with muscular movements of actual life.

a. Free-will puzzles vs. freedom in actual life.

"Free will" is like a mystery picture on a jigsaw puzzle where the pieces do not fit together. I suggest that misfits in free-will puzzles are the result of forms that trace back to Ideas of Plato and that inherit their limitations. Eternal impersonal ***spatial*** forms of platonic science do not fit the character of freedom. Critical review of platonic science leads to new ***temporal*** forms that do fit the character of freedom.

It is simple to state a facial solution to the puzzles. Puzzles of "free will" are set in situations that lack the ongoing ***stream of purposeful muscular movements*** through which persons exercise freedom. In such puzzles, persons are put into static positions, bodily and mentally, with scant opportunities for action. Periods of passive waiting are punctuated by isolated events. Metaphorically, the motoric beat of dance music is reduced to a progression of static chords on a church organ.

In a typical puzzle situation, a "research subject" is led to a test station, where the subject obeys instructions to remove some clothing, sit and relax. Experimenters attach electronic devices to the subject's head and other body parts. Then, while immobile, the subject is commanded to lift an arm "spontaneously." The attached devices report that mental activity leading to movement starts before the subject is aware of it. Such an investigation into a subject's awareness, called "free will," does not involve any freedom. Any will is that of experimenters. Some free-will puzzles even include brain surgery on a subject who has been bound to a table. Puzzlement about inconsequential "free will" in such situations is foreordained.

A deeper solution to the puzzles proposes a ***process of selection*** that embodies freedom in a form called ***Shimmering Sensitivity***. Engineered devices that generate Shimmering Sensitivity are to be built from Quad Net (QN) materials.

Proposed QN devices operate cyclically. At a critical moment in the cycle, the process generates co-existing germinal fragments of signals for multiple possible movements, perhaps appearing as tentative impulses ("Shimmering"). During the process and with Sensitivity to competing influences, multiple possible movements change into a single actual movement. To carry out such a change may require an exercise of freedom. Similar occurrences in actual life include making the next move in a chess game and picking up one dessert plate from a table of such plates.

I suggest that free-will puzzles confuse an extended process of selection with the shorter moment of change. Confusion may be compounded if a cause of change is attributed to awareness of mental imagery. Mental imagery, e.g., experience of movements, sights or sounds, is generated during some changes. Imagery can identify, index or encode selections and can be remembered. Colors are imagery. In device processes that generate Shimmering Sensitivity, imagery is used to make selections according to forms, e.g., a form for responding to a traffic signal: "stop on red, go on green." Imagery does not control Shimmering Sensitivity.

In contrast to puzzle situations, a person driving a motor vehicle in traffic is not confused about "free will." Motorists are continually exercising freedom by pressing with a foot on the accelerator and 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 are continually required to meet changing events and circumstances; and they make up a course of action and produce a trip that has been traveled. Some motorists initiate action frequently, seeking opportunities to complete the trip quickly; other motorists prefer a 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.

"Free will" does not puzzle athletes engaged in a sports competition. Sports arenas are places to exercise freedom; and teams and players are all determined to win.

Puzzlement about "free will" does not distract musicians performing in front of an audience. Musicians devote hours of practice and rehearsal preparing for just such occasions. Jazz musicians sometimes get to improvise during a performance.

Free-will puzzles do not detract from freedom exercised by motorists, athletes, musicians and others involved in actual life. The puzzles are inconsequential as well as fallacious. They do, however, lead to more serious questions; and a full and detailed solution shows new ways to approach weightier endeavors.

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

I investigate free-will puzzles and related matters by adapting principles of child psychology developed by Jean Piaget (1896-1980). Piaget was a natural scientist trying to account for mental growth of children. I modify Piaget's psychological principles for use as design principles in new technologies.

Repetition is a primal principle. Even in newborns' first reflexive behaviors, "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," where added behaviors "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 - 48.)

In other words, "habit," a primal kind of activity, is cyclical and repetitive; it is, in sum, ***self-perpetuating***. Self-perpetuating habitual behavior begins with reflexes. "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***." (35, emphasis added.)

In other words, beginning in early infancy, muscular movements are self-perpetuating and performed for their own sake. I suggest that 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 repetition and "doing it for the sake of doing it" are primal principles that lead in many directions, including scientific directions. In science, as we shall see, they lead to "invariance" and "conservation."

In my constructions, ***muscular movements*** make up the ground of ***actual life***. The word "actual" signals a discussion about muscular movements. Such movements include those involved in eating, digestion, breathing, seeing, walking, handling objects, writing and speaking. Children themselves define "life" first in terms of that "which has activity or a function or a use of any sort;" then "life is defined by movement;" finally life is identified with "spontaneous movement" of animals. (Piaget, The Child's Conception of the World (1929) at 194-195.)

My models are based on continuous and universal muscular activation. ***Every muscle is activated all the time***. In the timing device project, "an Eye for Sharp Contrast" (available on my website) every muscle fiber in the Eye is continually twitching; and the gaze shifts during each cycle. In actual life, biological muscles involved in heartbeat, breath and digestion all work continually.

I suggest that there is a ***plenum*** of muscular activation that is the ground of all activities of brains — insect, fish or human. In models, muscular activation is never lower than a level called ***tonus***, which sustains "muscle tone." However, in many situations, actual motion is intermittent or absent. Tonus is too weak to move a bodily mass. Balanced and opposing pairs of toned muscles keep the organism immobile much of the time. To produce actual muscular movements requires ***unbalanced*** muscular activation at levels higher than tonus. Varying levels of activation and varying levels of ***readiness*** are behind behaviors ranging from an immobile organism that awaits an external signal to violent enraged attack.

In actual life, activated organisms are ready for action. Activities requiring high 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 possible courses of action. In actual life, maintenance of high activation and readiness requires exercising freedom. In free-will puzzles, in contrast, persons do not operate out of high activation and readiness but are put into states of relaxation.

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, sensory objects, emotions, mental operations, plans) have ***control relationships*** with muscular movements. Control includes coordinating and organizing various movements. My approach aims first for operational control of movements and only at some later time for representational or symbolic control. Such an approach differs from computer models where representation is a basic principle. Here, representations are additional to other controllers and would be based in imagery that identifies, indexes and encodes bodily movements and positions, along with sights, sounds and words to be remembered during later operations. Development of imagery might re-trace the history of biological evolution: insects have scant imagery, reptiles have saccadic (jumpy, momentary) imagery, mammals have continuing imagery and human beings have self-conscious imagery.

In actual life, repetition and habits find ways to grow and develop when a child learns to "perceive things as we do, as objects that have substance, that are permanent and of constant dimension." Piaget, *The Child's Construction of Reality* (1936) at 1. Chapter 1 is titled "The Development of Object Concept." "Objects," according to Piaget, are psychological constructions; his approach is to state psychological processes or "operations" that perform such constructions. Pi aget thus teaches a practical and operational kind of epistemology or, using terminology of an engineer, a model of knowledge construction.

In "Constitutive Processes of Object Concept," Piaget compares "the formation of initial sensorimotor objects" through "the elementary processes of the child's intelligence" with "those used by scientific thought to establish the objectivity of the beings it elaborates." Piaget teaches that an infant's early mental activity evolves directly into the disciplined thought of a scientist. (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 essential to tactile and spatial perception 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 manual and mental operations based on muscular movements and their coordination. (Chapter 2.)

To sum up, Piaget teaches that psychological processes "build a spatio-temporal world of objects" through activity of the developing intelligence of an infant. In adapting such teachings, I construct distinct classes of "objects" and multiple "worlds." My constructions impose distinctions that are simplifications and approximations of complex bodies of phenomena. The chief purpose of such simplifications and approximations is to prepare materials for further constructions.

Piaget's initial sensorimotor activity generates what I call ***actual objects*** that are involved in muscular movements; and such actual objects are part of the ***actual world***. In my models, 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 dealing with the actual world, our brains operate in common ways that developed from those of early reptiles.

Similar psychological constructions produce a distinct and separate class of ***sensory objects*** from purely sensory activity. Sensory objects have no dependence on muscular movements but processes of construction of sensory objects are based on processes developed for construction of actual objects. We know by muscular activity that actual objects have a character, e.g., a rigid and permanent character or a fluid character. We impute similar characteristics to sensory objects.

Some sensory objects can be detected from a distance and others can be seen on a TV screen. Birdsong and celestial bodies (sun, moon, stars) are sensory objects. An object's class depends 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.

Sensory objects come in larger and more varied classes than actual objects. Persons share some sensory objects, such as celestial bodies, but do not share all sensory objects. I can understand English but not Japanese. Unlike actual objects that are tested by muscular movements, sensory objects can generate disputes about their existence or classification.

Purely mental objects are a third distinct class of objects: these objects start from actual objects or sensory objects; the person then uses additional processes to build a version that is detached from muscular movements and from any original context of movement. Mathematical objects such as numbers and geometrical figures are purely mental objects. This means that a mathematical object cannot have "weight," "mobility," "tactile pressure" or other muscle-based feature. A played tune and a spoken message may be reconstructed as purely mental objects.

Purely mental objects can be made subject to mental operations, e.g., operations that compare features and arithmetic operations. Such operations have a character different from that of actual life. In actual life, objects are unique and events are irreversible. Purely mental objects, on the other hand, come in classes of comparable objects and objects can be re-used, re-combined, re–organized, re-tuned, etc. Device designs herein are purely mental objects. Diverse kinds of purely mental objects include fantasies, e.g., imagery of a unicorn or fantasies of flying like a bird. Some purely mental objects are common to all persons, some are shared in a distinct community and others are entirely private.

Often, a person uses purely mental objects to try to control muscular movements during a performance, e.g., the purely 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 the class of such purely mental objects that are used as guides for actual movements. The concept of forms is subject to some expansion and development during the essay; throughout, it remains based in guiding muscular movements.

This essay constructs, compares and contrasts two classes of forms, namely, ***spatial forms*** and ***temporal forms***. Important spatial forms 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 construction is a unique spatial form and the uniqueness is proved. There are also ***empty forms*** that fail in attempts to guide actual performances, e.g., a form for flying like a bird by flapping one's arms.

As geometrical constructions 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 when trying to explain underlying principles of performance (forms) would take too much time.

c. Infantile repetition develops into scientific invariance.

In a further stage of development, psychological processes are used to construct a class of objects that I call ***invariant objects***. Invariant objects have a property in addition to those of prior objects, namely, a ***rule of invariance***. Like an actual, sensory or purely mental object on which it is based, an invariant object has a repetitive feature or character; but, in addition, it has that feature or character ***every single time*** and it ***cannot lack that feature or character***. A rule of invariance can be imposed on the basis of, e.g., design, inherent operations, experience, reason, authority, habit or lack of imagination. Mathematics and sciences are built around minimal 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."

Rules of invariance can have many beneficial advantages that encourage efforts to construct and impose them. An invariant object has a certain reliability; it can be re-used easily, without need to weigh possibilities. "Uniform" objects — 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. Commerce requires a currency that is at least approximately invariant. Something that lasts— that endures "the same" over a lengthy period of time — has inherent value based on that fact alone. In the final scene of *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." I suggest that life might 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.

Ancient Greek philosophers embarked on "the search for invariants, which is the definition of science." (de Santillana, 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 itself invariant 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 a world 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. 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. A self-declared platonist, Roger Penrose, wrote about "the mathematical scheme which governs the universe." (Penrose, 433.) Richard P. Feynman was sure 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." (Feynman, Character of Physical Law, 151.) Artificial intelligence pioneer Marvin Minsky declared: "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." (Minsky, § 30.6.)

I suggest that the foregoing assertions are erroneous, that certain errors can be identified as limitations of platonic science and that such errors and limitations are overcome by means of new temporal forms that lead to new technologies.

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" are unsatisfactory even for the purposes of Augustine (354-430), the inventor of "free will." (Taylor, 138.) ["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."] In brief, "will" and "free will" fail to connect to muscular movements of actual life.

A ***metaphysical construction*** is one where purely mental objects exist and act in an imaginary domain, such as the imaginary domain of a geometrical demonstration or a domain implied in a physicist's chalkboard diagram. Aristotle's metaphysical psychology was behind the invention of "will." (Taylor, 137.) Expressly stated or implicit in metaphysical constructions of science or technology is a claim to connect to actual life, an ***application*** of the construction that would guide muscular movements of persons, e.g., one who is building devices from materials. Some metaphysical constructions, e.g., in plane geometry and Electromagnetic Waves, do have actual applications; but other constructions do not. Without actual applications, a metaphysical construction is empty, e.g., flying like a bird, that do not guide a person's actual muscular movements. An empty metaphysical construction exists only in imagination and cannot be connected to actual life.

I suggest that "will" and "free will" are empty metaphysical constructions. For example, one notion of "will" is that, while exercising the "power to confer or withhold all-things-considered assent," it is "will" that activates muscular movements. Such a notion, if substantiated, would apply directly to actual life. However, such notions have not acquired substance. Modern science provides no suggestion of such an activation that is any more satisfying than Descartes' fantasy connection through the pineal gland. As discussed in § 6, the Quad Net Model proposes a process that generates mental imagery of multiple possible outcomes while they are changing into a single actual muscular movement; however, there is currently no place for "will" in the Quad Net Model.

In sum, concepts of "will" do not connect to muscular movements. "Free will" does not connect to anything at all. It is a "power of choice" that ignores difficulties of performance in an actual, sometimes reluctant world. Freedom requires readiness to generate possible choices before a particular choice can be made . "Free will" denotes an empty choice that needs no readiness, a choice without stakes or effort, like gambling at roulette with unlimited play money.

If I were to play with a metaphysical construction of "will" or "free will," I would start with the principle of repetitive "doing for the sake of doing" that is observed in an infant's prolongation of sucking beyond the need to satisfy hunger. I would say: that is done willfully which is done simply for the sake of doing it. A person is free when doing something involves a transformation or choice where multiple possible ways of doing it change into a single actual way of doing it – or not doing it. However, such play does not address puzzles of "will" or "free will."

Freedom is represented herein, e.g., by motorists and musicians, by a baseball player at batting practice, by runners in a footrace, by a diner choosing from a menu at a restaurant and by a jury rendering a verdict. The forms of such exercises of freedom are not simply willful – not done simply for the sake of doing – but have developed through experiments and adjustments to serve multiple purposes.

Although metaphysical constructions of "will" and "free will" are empty, the wider history of metaphysical constructions shows facts of substance and promise. Certain metaphysical constructions have led to tremendous successes of platonic science with wonderful actual applications in practical technologies and with 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 ether).

Such examples also demonstrate that metaphysical constructions incorporate errors. Errors in the examples (invalidity of "absolute time and space" and "luminiferous ether") were shown by Einstein's superseding construction, the Theory of Relativity (1905), which astonished many scientists, also showing 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. Technology based on metaphysical constructions can outlast belief in the constructions themselves.   Astronauts' navigation uses physics 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 is that "light is photons" is "true" and that "light is waves" is "false." Between the introduction of Electromagnetic Waves in 1865 and 1905, physicists believed that "light is waves" was true; but Einstein (and others) showed such beliefs to be untenable. In both statements, "light" refers to something "real" and such reality is connected to a mathematical construction, either "photons" or "waves." Physicists now hold that mathematical photons have some connection to reality that mathematical waves lack (showing the metaphysical character of Electromagnetic Waves). Despite the inferior status of waves, technologies based on waves – e.g., microwaves and lenses that aid vision – are so firmly established that their development progresses 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." To help aim at the goal, critical reconstruction of existing and past attempts can suggests paths to success and help to 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. Constructions in this essay adapt the new principles to existing principles such as symmetry and invariance.

I investigated the physical principle of freedom, ***Shimmering Sensitivity***, during

2004-2006, leading to development of Quad Nets for its embodiment. Here, discussion of Shimmering Sensitivity is at the conclusion of the essay, with other constructions leading up to it. Simpler timing device constructions have been designed that I suggest function like rudimentary parts of brains, e.g., “An Ear for Pythagorean Harmonics” (2009) and “An Eye for Sharp Contrast” (2011).

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 kit of parts form is used extensively in this essay and in other materials on my websites. The timing devices kit of parts resembles the kit of standard electronics components, but with new and different signals, devices and operations. The timing devices kit is an application of the more abstract kit of collective Quad Net devices. There are currently no working models of any of the devices and 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 new and improved devices and principles. Operational systems that use manufactured timing devices and Quad Nets — especially new and improved versions — will be actual applications of my metaphysical constructions.

2. Nietzsche’s “will to power” shows the fallacious character of metaphysical constructions that fail to connect to actual life.

Nietzsche invented “will to power,” declared it the sole cause of actual life and based an elaborate construction on it. The construction is flimsy and childish and reveals the fallacious character of such constructions, including those of Greek philosophers who founded platonic science and those of their modern inheritors. Nietzsche himself criticized such constructions on grounds similar to those I state.

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

Nietzsche begins his construction with “our world of desires and passions.” He proposes that there is no “other ‘reality’ besides the reality of our drives.” He “make[s] the experiment” that such a reality is “*sufficient* for also understanding … the so-called mechanistic (or ‘material’) world.”

The construction continues by positing “several kinds of causality,” including “the causality of the will.” Nietzsche 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 transcends 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 ground his construction in 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.) Value establishes “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 such constructions an imaginary, metaphysical domain is occupied by invariant and purely mental objects that are declared to control actual life. Such constructed mental objects include respectively, platonic Ideas, Laws of Physics, and Will to Power. In all three cases, the construction is single-minded: a single kind of mental object is supposed 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 drives and “more” values are the only sustained features, some “more” values lead to very little more while other “more” values lead to a lot more; and the differences are differences in power. Will to power is itself a powerful value — it is by definition the sole generator of all value — 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’s construction, you must embrace and uphold will to power in a single-minded way and you must get more, more, more!

The “will to power” has not led to positive developments. 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.”] Criticism of Nietzsche’s will to power recapitulates criticism of platonic science. The tradition of criticism started with Aristotle, whose views and methods were quite different from both Plato’s and Nietzsche’s. (de Santillana.)

“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.)

Of course, the “will to power” is older even than Thrasymachus, Plato’s callow and inept spokesman for it. Like Plato, Nietzsche did not ground his inventions in actual life but rather in mental conceptions that he preferred to actual life. For me, actual life is grounded in muscular movements and bodily activity. Most of my actual activities are directed towards satisfying essential bodily needs and satisfying further body-based desires for home, comfort, movement, adventure, sensation and society. These have little to do with Nietzsche’s kind of power. Concerns in my life have developed as I mature. Nietzsche’s kind of power has not been a motivation. My values and moral directions come from a spiritual source and call on me to oppose Nietzsche's kind of power rather than inflating it.

In sum, Nietzsche's construction of "will to power" does not connect to my actual life. Nor does it stand up to critical examination. He starts the construction on a base of "our world of desires and passions." Then, he declares that his construction encompasses mechanical and material causes. He never questions whether his construction has fallen off its base or whether the base has shaped development. He never evaluates his experiments, risks or 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 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" are important for some causal investigators but by no means all. Wallace's 2-volume *Causality and Scientific Explanation* has but two references to "freedom," quoting scientists who decline 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, so that "the causality of the will [i]s the only one." Without any consideration of mechanical or material phenomena, he reduces them to "will" – "as *my* proposition has it." He conflates controlling through physical mechanisms with controlling through will or through desires. He denies any independent character to mechanical or material causes. He claims to control them all entirely through his imagination. His "will to power" construction is indistinguishable from a "wish" construction.

Nietzsche uses metaphysical constructions like "the 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 overall impression is that self-intoxicated Nietzsche had little regard for solid construction. His "will to power" has no 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 he called "the two worlds," where a metaphysical world of permanent knowledge supposedly controls a transient world of appearances. (Kaufmann, vol. II, 76.) He identified the commonality of two-world constructions in ancient and modern sciences.

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.

Most important, Nietzsche tried to ground his construction in “a kind of instinctive life” that revolved 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 seeks to integrate the multiplicity into a living organism while, in contrast, platonic science seeks first to separate the elements and then to control them.

I suggest that Nietzsche carried out a partially successful investigation into his own primal psychology. Unfortunately, the fruits of his investigation were not the sought-after keys to the universe. They were, rather, certain childish thought processes that Nietzsche dressed up in grandiose phrases, projected as imagery of actual life and inflated into a comprehensive world-view. Because Nietzsche’s thought processes were authentically childish, they incorporated primitive aspects of actual life that are very different from the detached constructions of platonic science. The surprising and even shocking juxtapositions appeal at first to childish dispositions and then reveal genuine substance for critical analysis. Seen next to the vibrancy of 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 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. A chief difference is that an adult has learned from failures of ego-centrism and therefore limits and constrains acts 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 novel, 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 the essential power of desire, which is the only power that is recognized.

Like children's "artificialist" explanations, Nietzsche's "will to power" explanation does not require proof. He sees that his concept might apply to some actual activity and any such application is sufficient for 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 clearly reveals how, in such a construction, particular mental processes are first grasped through introspection, then 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 discussed below adapt the method and employ it in new ways and with different forms and embodiments of a technological character.

3. In metaphysical constructions that were developed by ancient Greeks through "platonic science," an imaginary domain is occupied by mental objects called "Ideas" that are impersonal and eternal, that have the character 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 catastrophic Peloponnesian War that ruined Athens and during Plato's public career of supporting aristocratic and oligarchic parties 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.)

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

Plato's goal of imposing hegemonies in political, philosophical and moral matters 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 about which statements are "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 sciences and shapes their content, e.g., as noted above, through "the search for invariants, which is the definition of science." (de Santillana, 218.) Advocates of the "modern scientific view" (Minsky, supra) do not simply "search for invariants." They want to allow as legitimate only a particular kind of invariant.

Aristotle, who "swerve[s] away from mathematics" and, instead, "takes his start from things," concurs in the invariant approach and declares "There is no science except of the general." (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.)

"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 courted by marketers of clothing fashions, hairstyling trends and popular culture. Judges 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. The supposition in ancient times, same as today, was 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 other words, I suggest that platonic Ideas identify purely mental objects that are constructed by means of psychological imagination and continually reconstructed by the same means. Such constructions resemble those introduced in § 1 as part of the child's construction of reality and those discussed in §2 in connection with Nietzsche's will to power. Constructions revolve around psychological processes. The author of the construction obtains imagery of such processes, e.g., by introspection and observations, endows the imagery with supposedly-powerful "impersonal invariance" in an imaginary domain, elaborates the imagery in constructions and declares that imagery so endowed is in control of actual life. Impersonal invariance supposedly overwhelms any influence arising from personal efforts or personal favor. Advocates of the imagery claim an authority that transcends its "human-all-too-human" origins and that promotes its hegemony.

c. “Sufficient reason” turns invariance into symmetry and eternity.

“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. I suggest that both invariance and symmetry are mental constructions based on repetition in action and sensation.

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 situations such as “empty space” can be constructed where rules of invariance impose symmetries. Platonic science treats such special situations as establishing the ground of all phenomena.

An important application of the principle of sufficient reason is Newton’s First Law of Motion, which states, in effect: “An object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force.” Newton’s Laws and motions thereunder take place in an imaginary domain of empty space that starts off devoid of influences (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 other direction 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.

Applied to empty space, the principle of sufficient reason says that every point in empty space participates in a “sameness” that enables one geometric figure to be “superimposed” in the imagination 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.)

As shown by Newton’s First Law, there are some situations where the principle of sufficient reason can be applied to temporal events as well as to spatial symmetries. “Speed” is treated the same as “direction.” Application of both the invariance principle and the principle of sufficient reason generates 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***.

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 chiefly characterized by symmetrical features that establish an "eternal, impersonal" character. Such invariant objects have a resemblance to actual objects that is like the resemblance of Greek gods to human persons. According to many teachers, e.g., Plato, such invariant, impersonal and purely mental objects in imaginary domains control — or should control — actual life.

d. Platonic constructions have the character of geometrical space.

The course of development of platonic science added additional specific character to the objects of its constructions. Seen in retrospect, that additional character is ***geometrical*** and has, specifically, (1) a characteristic of ***rigidity*** that is based on ***invariant symmetries***, specifically, homogeneity and isotropy introduced above; and (2) a characteristic of ***continuity***. Plato's Ideas incorporated such rigidity and continuity; modern physics is built around generalized "spaces" that maintain them.

As discussed below, new proposed temporal forms have a different character. Invariance, symmetry and continuity are not "laws" that are universally inherent in things but are, instead, ***constitutive principles*** by means of which we can construct, describe and control events, e.g., using technology. Some temporal forms are invariant and continuous, e.g., a beat controlled by a metronome. In contrast to invariant and continuous temporal forms, there also exist temporal forms that have multiple possible asymmetrical outcomes and/or that are discontinuous — e.g., forms that describe overtaking during a race contest and a diner's choice in a restaurant during which multiple possible dinner orders jump around in the mind before changing into a single actual dinner order. Such temporal forms have ***critical moments*** of change that do not fit into spatial forms.

Using de Santillana's *The Origins of Scientific Thought* (1961) as a 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 was reported to have unified them with, *inter alia*, 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 their music theory, an important focus, a system of proportional relations unified the varying sizes of strings and tubes in musical instruments and the corresponding musical tones. "Pythagorean harmonics" stated specific proportions or ratios.

"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 Pythagorean and Platonic physics 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."

Pythagoreanism upheld a visionary cosmology based on music, number and geometry. The vision was extended and solidified 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 distinguished in a way closely resembling that used to divide Plato's 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.) It thus appears that Parmenides was a source of Plato's "divided line" demonstration and desired hegemony of eternal impersonal invariants.

De Santillana offers translations of Parmenidean fragments that he interprets through a puzzle called "what is Being?" That is, Parmenides declares the supremacy of "Being." In the puzzle form suggested by de Santillana, "Being" is something you know 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.)

The answer to the puzzle, according to de Santillana (95, emphasis 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.)

My approach does not depend on philosophers or their constructions. However, such constructions identify characteristics of our own conceptions of space that are congruent with those of ancient Greeks. Our conception of space, like theirs, is of an empty container that can be identified with metaphysical constructions. Such space is subject to invariant symmetry and continuity conditions; therefore, it endows constructions in it with invariant characteristics of rigidity and continuity.

"Rigidity" is based on invariance of both homogeneity and isotropy. Consider the possibility of deforming geometrical space by stretching, bending or twisting. Consider the fate of a geometrical figure when space is deformed. Look for deformations that preserve 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 inflation and deflation of a perfectly spherical balloon; figures drawn on the surface of such a balloon are preserved 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 preserved as invariants. In other words, proportions are maintained if all subdivisions of space change together in an organized way. Then, proportional relations remain as linked invariants that make up an invariant structure. 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 continuous organized ways. 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 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 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 where each runner's tempo of muscular movements is controlled through sustained goals empowered by competition but also 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 preserved 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., switching between listening and speaking and the changing gaits of a horse. A class of discontinuous transformations in materials are called ***phase changes*** driven by temperature changes such as occur when liquid water turns into ice or steam. In models set forth herein, important "selections" are discontinuous transformations that occur when multiple possible courses of action change into a single actual course of action. Some selections occur when a person makes a choice, e.g., choosing a meal from a menu in a restaurant, when multiple possible orders being entertained in the mind suddenly change into a single actual order spoken to the waiter.

Race contests incorporate “critical moments” when one runner overtakes another runner.   Menu selections incorporate “critical moments” during which multiple possible courses of action suddenly change into a single actual course of action. Such “critical moments” identify temporal forms that are outside the reach of platonic science and that sometimes involve exercises of freedom.

4. Modern versions of platonic science construct imaginary spaces in which passive bodies undergo quasi-static changes according to eternal linear forms called "laws of physics" that supposedly control everything.

   a. Modern platonic physics has advocates and alternatives.

I offer views of modern physics that differ in content and approach from prevalent positions that have been called "the modern scientific view," as noted in § 1.c. Views herein are organized around new technologies that have a revisionary basis.

Richard P. Feynman advocated a platonic view of physics in *The Character of Physical Law* (1965), also quoted above. The text is based on 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 summarize the platonic view.

Of course, not all physicists are platonists. An "operational" view was presented by P. W. Bridgman (awarded the Nobel Prize in 1946) 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.

As for myself, I build things in my imagination, aiming to reach certain goals (freedom) and committed to certain principles (spiritual). My approach is opportunistic, based on whatever best develops my constructions. Such constructions are provisional and germinal; and my "operational" notions are based on Piaget's principles rather than on Einstein's (the model for Bridgman).

Feynman taught that the most important scientific "fact" is that "all things are made of atoms" (Lectures I-1-2) and, more generally, that laws of physics control the Universe. In *The Character of Physical Law*, Feynman began 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." (Character, 14.) In the different view presented herein, the Law of Gravity is the most successful theory of platonic physics because it is grounded in empty space, which was favored by ancient Greeks for similar reasons.

According to Feynman, "great general principles which all the laws seem to follow" include "the great conservation principles." (*Id*., Chap. 3.) 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, angular momentum and energy; and "constants of the motion" based on such principles are used to calculate and predict actual motions of such billiard balls and particles.

Conservation of momentum is based on spatial homogeneity previously discussed. 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 constructions are expressed as conservation of momentum and angular momentum in constructions of modern science.

"To … our list of conservation laws…, we can add energy. It is conserved perfectly as far as we know." (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 — 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 laboratory production of snowflakes from gaseous water vapor. The principle of energy conservation requires "state" conditions, e.g., a defined and uniform "temperature." There is no defined "temperature" in the examples. Instead, hot is changing to cold.

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 have features that suggest critical comment. As discussed above, chief successes are set in empty space. Scientific reasoning based on empty space started off in ancient Greece with geometrical reasoning and developed historically from that base. Newton's primal publication, *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 solar and planetary masses to geometrical points or "corpuscles." The approach becomes problematical when complications are introduced. "Three-body problems" became evident during the 18th century. "Chaos" 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.

The great saga of development of electricity and magnetism is discussed in § 6.d. Major events in that saga 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 of a metaphysical kind. Maxwell used empty space symmetries, conservation principles and continuity assumptions to construct his "displacement current" and the "light is Electromagnetic Waves" model. Einstein's special and general theories superseded both Newton's and Maxwell's models but retained and developed their spatial approach.

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.)

A different view 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 in § 5.c, "analytic 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. Analytic mechanics, e.g., statistical mechanics, turns its back on such facts.

Thermodynamics is the branch of physics that deals with properties of and changes in material bodies in general. Specific topics in ***materials science*** deal with particular kinds of materials, e.g., metals and semiconductors. Truesdell (Rational Thermodynamics, 1) contrasts 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.)

My view differs from those of both Feynman and Truesdell. 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 mathematical and/or device models of changes in material bodies expressed in terms of conversions and interactions that can take multiple forms but that have a single common basis in "energy." In my view, current platonic conceptions of energy are superficial and rudimentary but provide suggestions for development. My conception of energy is constructed functionally as that which multiple forms of activity have in common and as that which passes between forms of activity. In the simplified timing devices system, energy is in the form of "action pulses" that are all identical, as discussed below.

Mechanics, e.g., classical mechanics (Goldstein), occupies one domain of investigations into energy. Electromagnetism and electrical engineering occupy another domain. Unification of the two domains (mechanics and electromagnetism) is possible as to some aspects but troublesome overall. (Penfield & Haus.) Thermodynamics is a separate domain of investigation into energy, an alternative to other approaches rather than subject to them.

Thermodynamic models do not acquire the rigor or power of mechanical models just because it would be gratifying if that were so. Feynman and other platonists use gravity as their exemplar but no other scientific concepts are as successful as theories of gravity. Theories of gravity are based on the geometry of empty space.

"Conservation of energy" is different from conservation of momentum because energy conservation in material bodies is imposed through equilibrium constraints and what Truesdell calls "constitutive relations" or "constitutive laws" that depend on the situation and on particular properties of materials; while the stronger momentum 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." *Rational Thermodynamics* at 13. In other words, the first "law" of thermodynamics, "conservation of energy," is based on the constitution of the body rather than being an inherent feature of the Universe. An actual body, e.g, a body of water that changes from liquid to gas to solid, with a constitution that conforms to and illustrates the law most of the time may not be controlled by law during certain events, such as the formation of snowflakes.

b. Minkowski's "union of space and time" illustrates puzzling claims of conceptual hegemony.

In a 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."

Although the novelty of Minkowski's claim has passed, Stephen Hawking's *A Brief History of Time: From the Big Bang to Black Holes* (1988) (21, 24) echoes it: "…relativity…has revolutionized our ideas of space and time" … "a four-dimensional space called space-time".

Such claims remain puzzling for several reasons. Foremost are actual distinctions between space and time. That is, speaking from the perspective of actual life, I have an overall 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 goals in space, my end in time is concealed from me; and I move towards it with only guesses about how to guide my deeds.

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 such symmetries as to space but do not change their power, at least as far as actual life is concerned.

Symmetry comparable to spatial symmetry is not present in time because of the "arrow of time." This common phrase stands for the pervasive fact that all actual changes share a specific direction. That direction is an asymmetry. In actual life, it is not possible to put an egg (e.g., Humpty-Dumpty) together again after it is broken. The word ***irreversible*** is used to specify changes where return to a previous condition is impossible. Conversely, changes where the initial position can be recovered are ***reversible***. In the actual world, all changes are irreversible. There are "approximately" reversible events, e.g., in videogames and movements to and fro in space — but even these events occur at different times in a changing world and may be thwarted by irreversible events such as deaths and breakages.

Irreversible changes occur in actual life when hot steel is quenched, when snowflakes form in a laboratory and during sports contests and trials in court. Each of these events is carried out intentionally to produce such changes. I suggest that irreversible events are normal or default kinds of event in actual life and that reversible events are special, e.g., like winning a rare reversal in a court case. In contrast, imagery of platonic science teaches that actual life is controlled by reversible events and that reversible events add up to irreversible events. The actual world I experience does not match imagery of platonic science.

The principle of sufficient reason applies to empty space because empty space is highly symmetrical. The principle of sufficient reason applies to time only in special cases. One special case is ***time-invariance***, comparable to isotropy. For example, among electronics devices, there is a class of "time-invariant systems." A time-invariant electronics system, e.g., an AM radio, has identical capacities all the time. Any time you want, you can turn the dial and try to get a station located at a certain frequency. A time-invariant system is not constrained by memory; it doesn't matter what station you listened to last. Time-invariance and constraint by memory cannot co-exist in such a system. The entry of a memory breaks temporal invariance. The function of memory is to help construct possible alternatives to action without memory. (See § 6.c.) Time-invariance excludes alternatives based on memory. In actual life, in contrast, behaviors are subject to memory and to alternatives, e.g., preset radio stations.

In a similar way, "equilibrium," the "time-invariant" ground of the First and Second Laws of Thermodynamics, is inconsistent with memory or alternatives.

Notwithstanding clashes between platonic imagery and actual life, some scientists claim hegemony for their 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" during repetitive muscular movements, which can be highly ordered activity even though it is not the "equilibrium" kind of order that Hawking's ideas require. Repetitive muscular movements can build a wall out of bricks. The concept of entropy was invented by Rudolf Clausius (1822-1888) and has only limited and specific applications. Clausius' entropy applies to bags of gas that are "relaxing towards equilibrium," not to purposeful muscular movements.

Statistical mechanics, invented by Josiah Willard Gibbs (1839-1903) and the source of "entropy is information" notions, applies only to static systems. Such concepts do not apply to transformations that produces individualized snowflakes. Nor do they apply to transformational activities of a high-dissipation brain that is burning 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 increases regardless of whether activities grow more "ordered" or more "disordered." "Entropy increases" do not control "order."

Arguments about time based on entropy, such Hawking's, are empty. They do not answer questions about the clash between Minkowski's views and the facts of actual life. From the perspective of one grounded in actual life, Minkowski's prediction that "space by itself, and time by itself are doomed to fade away into mere shadows" was puzzling when he made it. The prediction has proved to be false. Only physics buffs and professionals think about a "union of the two;" but all persons, including physicists, continue to use clocks without reference to meter sticks and vice-versa. 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. The primal linear form of platonic science fits into Minkowski's spatialization of time, disregarding the character of time in actual life.

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 with various symbols and applications. The point of origin is the formula: distance = rate × time or d = r×t. One early 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 previously, that depend on properties of materials which exist only for certain ranges of activity.)

As the name indicates, a linear form is based on the form of a geometric line. The form for a line in analytic geometry is $y=a\times x+b$; an even simpler and more popular form for a line is $y= a\times x$. Then the line passes through the origin of the graph.

I first focus on an example of the linear form that is most suitable for discussion of Minkowski's union of space and time. The exemplary form is called 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. 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 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 applications of the 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 the geometrical linear transformation exemplifies 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 ***invariant proportionals*** of Pythagoras and Parmenides that characterize the rigidity of geometrical space. Homogeneity and isotropy appear as fixed relations among the $(a_{11}, a_{12}, a_{13}, a_{12}, a_{22}, a_{23}, a_{31}, a_{32}, a_{33})$.

Linear forms have many advantages that make them the favorite form of science and technology. Linear forms separate invariant features from variable features and uses invariant features to anchor easy arithmetic operations + and ×, making up a convenient computational device. The linear transformation develops into classes of linear transformations that can be organized by means of powerful tools. Easy, useful and convenient linear transformations are a basis of ***linear algebra***.

What Lorentz, Einstein and Minkowski did was to employ 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}) are set forth in the well-known Lorentz transformation.

The Lorentz transformation has the effect of turning time into a spatialized variable and making time part of a rigid system of proportional relations. The system is not quite invariant 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 speed between two frames of reference (X and Y) and such speed can change. In applications of the Lorentz transformation, however, the speed between frames of reference is typically held fixed and the values for a_{jk} remain fixed like fixed proportionals of Pythagoreans.

Spatialized time is certainly useful for some purposes, such as purposes motivating Lorentz, Einstein and Minkowski, notwithstanding puzzling features previously noted. A chief purpose was to describe a certain kind of activity, namely, Electromagnetic Waves traveling in empty space. Such waves are reducible to perfectly "invariant" phenomena. The usual imagery uses a "traveling sine wave," where "sine" denotes a repetitive mathematical function. In imagination, an infinite sine wave repeats both in space and in time, thus in boundless eternity. Such imagery of waves rather resembles some phenomena of actual life, e.g., music in an otherwise silent concert hall. Such properties of spatio-temporal waves in music, e.g., in plucked strings, organ pipes and musical tones, made them attractive to ancient Pythagoreans and to platonic scientists. Such waves have important, if limited, uses, e.g., in the "spherical harmonics" of atomic physics.

If the only 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, I develop 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 the step 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. The character of the more general version 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 character of the original version if all matter is excluded.

The old 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 old form, the new form interweaves slowly varying proportionalized "bindings" with quick "changes" to make up a convenient and useful device. "Linear" advantages of the old 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. Explorers might think that the oceans had disappeared.

In actual life, 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. Such transformations discussed below include quenching of hot steel and water vapor freezing into snowflakes. As the name indicates, a discontinuous transformation is a sudden and complete change of form. In a radioactive transformation, one kind of atomic nucleus suddenly changes into another kind of nucleus. A particle is thrown out, called "radiation." 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. 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 will have undergone 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 sum, platonic successes that culminated in Einstein's theories were grounded in empty space. Matter was reduced to points that embodied conservation principles. The platonic approach failed to model important phenomena of matter such as radioactive transformations. Other famous failures included photo-electric effects, black-body radiation and the spectrum of emissions from ionized hydrogen. Indeed, material phenomena in general were shrouded in mystery, except to the extent thermodynamics had unraveled seams in the shroud.

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

While some scientists and engineers were investigating gravity and electricity, other scientists investigated properties of matter, especially "thermal properties" of matter that are controlled by heating and cooling. Some investigations into thermal properties were based on symmetries, e.g., symmetries found in a crystal gemstone or maintained in a volume of air confined to a cylinder with a workable piston. Such accessible forms of matter are relatively rare in nature, although occasionally found, e.g., in clouds that produce snowflakes. Mostly, physical scientists have prepared materials specially for purposes of investigation and useful applications. Specially prepared materials include chemical reagents and metal alloys made according to a recipe. Platonic science requires a clean work bench and careful records of results. Only through such methods can invariance be established.

Some phenomena are rather closely modeled by platonic science but other 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 models of formation of pearlite during very slow cooling of hot steel. Phenomena that are poorly modeled by platonic science include the formation of martensite during very fast cooling of hot steel and the formation of snowflakes. Platonic science has successfully modeled a ***critical point transition*** using the quasi-static, mathematical Ising Model. The model suggests some features of the entire class but by no means exhausts the subject matter. In proposed technology, Quad Net devices pass through an activated kind of critical point transition during critical moments of Shimmering Sensitivity.

The Ideal Gas Law (pV=RT), a linear form, "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 in a vessel of volume V. The "gas constant" R is a fixed number that depends on the units used to measure the other quantities. E.g., R=8314 joules per degree Kelvin. Hence, the Ideal Gas Law states a mathematical relationship between the temperature, pressure and volume of a confined gas that is ***the same relationship*** for a class of gases. The ***invariance*** of the Law class makes it a "universal law." The Ideal Gas Law is a successful platonic form.

Another set of "universal principles" was discovered 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. 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 under controlled circumstances, $L_{ij}=L_{ji}$, which is a ***symmetry*** that is called "reciprocity."

The significance of the Onsager reciprocity relations is controversial. In the Nobel Award Ceremony Speech 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 special character 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.)

I suggest that all constructions of platonic science that involve material bodies have such a special character even though they are acclaimed as "universal." As noted above by Truesdell & Noll, the modern physics of fundamental particles "concerns solely the small particles of matter" that have a conceptual basis in geometrical points. Statistical mechanics, Onsager's field, is based on the mechanics of geometrical points maintained in static systems. (Gibbs.)

Thermodynamic constructions have their own special character. A body under study is made subject to constraints that control its activities. Any uncontrolled activity is also tightly constrained. 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. Passages of work or energy through the boundary 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 of thermodynamics, a body must be simple, passive and highly controllable. Living animal bodies do not have such a character.

In thermodynamics, a chief focus is on the temperature of the body. There are various possibilities. Perhaps one temperature applies to the whole body, a special kind of situation with a particular nature, or perhaps there is a more general spread of temperatures over the body, which may be described as a temperature gradient. An underlying question is whether a temperature can always be defined or whether there are situations where a temperature cannot be defined.

Strictly applied, the First and Second Laws of Thermodynamics apply only to bodies ***in equilibrium*** or "close to equilibrium." Equilibrium means that the temperature is always uniform over the entire body. I suggest that a body in equilibrium has a certain symmetry that enables practitioners of platonic science to construct Laws. On the other hand, a fire poker with one end in a steady fire and the other end in a bucket filled with ice can have temporal invariance even though it is not in equilibrium. Methods close to the Laws of Thermodynamics "turn out" to be workable for the fire poker. Such methods have limitations, however. In particular, they do not apply during discontinuous transformations, which occur "far from equilibrium." They do not apply to martensitic transformations of steel or to the production of snowflakes. Nor do they apply, I suggest, to discontinuous transformations that occur in brains.

"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. In imagination and using spatialized time, the system can be lifted out of one moment and superimposed onto another moment and the two systems are, for purposes of the science, "the same." 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 investigator is to maintain the system in such balance. The investigator then introduces an imbalance and multiple activities adjust to remove the imbalance. Adjustments are in the form of shifts in temperature or other quantities. Then things quiet down again 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, the researcher first prepares a body of liquid in which equilibrium is established. The researcher then introduces imbalances in heat, and the population of a particular chemical species without changing other conditions such as pressure and populations of other chemical species. Each imbalance will cause a direct flow (heat imbalance causes a heat flow) that relaxes and removes the imbalance. There will also be indirect flows (heat imbalance also causes pressure re-balancing and re-balancing in populations of other chemical species). The Onsager relations apply a geometric method of "fixed proportionals" to describe such relaxation flows.

Generalizing the above method, a scientific investigation begins by establishing complete control over a physical domain. The investigator imposes a ground condition, e.g., uniform conditions that approximate those stated in a mathematical model. In thermodynamic studies of materials, an equilibrium ground condition is established. Next, the investigator introduces a small and controllable variation from the ground condition that leads to another condition that is compared to the ground condition. Then, there may be a return close to the ground condition like that in the Onsager Relations, which I call a ***reversion***, with governance of the reversion through a linear relationship being commonly imposed. Hooke's law for elasticity (F = –kx) is the primal example of form for a reversion. Or, instead of a reversion, the ground condition may undergo a ***linear shift***, that is, a change that shrinks smoothly to 0 as the size of the variation shrinks to 0 — then successive shifts can be tracked, usually with an eye out for a linear relationship between variations and shifts. Such results are described by ***quasi-static*** forms discussed below. Thus, scientific investigation that is grounded in equilibrium systems leads to linear forms.

I further suggest that the mathematical models used in such investigations are grounded in equilibrium and relaxation principles and that such principles and models impose invariance and prohibit alternatives. According to the models, a system has a single specific functional form, called the equation of state, that is specified by state variables. With an equation of state, any process that begins at a specific initial state of the system and that ends at a specific final state will result in a single common change in the system regardless of the nature or speed of the process that moves the system between the states. Conservation of energy is implicit in the equation of state. The root meaning of conservation of energy is that results do not depend on details of the process. For example, slow sliding of a bag of gas from point A to point B in a room has the same result as pounding the bag across the room with a baseball bat, so long as there is enough time for the gas to relax before measurements are made. The same rule applies to any system that is subject to rules of equilibrium. Such a rule does not apply, of course, to the treatment of an animal body such as that of a human being. Such rules do not apply to discontinuous transformations like those where a single body of gaseous water vapor can generate a multitude of different snowflakes. Nor do the apply to a cycling system that generates an entirely different set of snowflakes every time.

e. "Quasi-static changes" effectively describe some slow transformations, e.g., formation of pearlite in steel-making; but such changes fail to describe similar faster transformations, e.g., formation of martensite.

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 ***temporal 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 supposed state-like units of matter.

In thermodynamics, invariance is supplied by equilibrium. Equilibrium is simple to test, as set forth above: 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." Thermostatics is restricted to unchanging systems that are the subject of ***statistical mechanics***. Thermostatics is the basis of "entropy is information" notions. "Entropy is information" notions strictly apply only to systems in equilibrium that can never change.

Thus, the founding text of statistical mechanics by Josiah Willard Gibbs employs linear formulations of mechanical "coordinates" p, q and a. He states a principle of "conservation of energy" and focuses on conservative systems and on dynamics completely determined by a single common function.

"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)

Investigations of systems described by Gibbs have been very fruitful. There are, however, many other systems that do not fit the description and that do not fit principles of statistical mechanics. As shown below by means of A Dogtail for Wagging, muscular movements do not fit principles of statistical mechanics.

In order to escape from equilibrium, scientists introduced a variety of methods and techniques, especially 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.)

Some phenomena can be modeled by quasi-static processes but other phenomena are not described by such models. Fortunately, phenomena come in wide-ranging classes that show clearly how quasi-static 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. 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 class of phenomena is that involved in the technology of audio circuits. Designers of audio circuits 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 an amplifier, operate very close to the ideal standard set by perfect linearity. Other components, such as loudspeakers, are more problematic and, therefore, better suited for this discussion.

In a typical audio installation, the best loudspeaker performance is obtained at low volumes 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 the pure frequencies of a flute may lead to sound waves with an ugly spread 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 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 substance inside pipes, 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 imaginary flow, 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 activities of actual materials limited to certain situations.

When the pressure and flow rate become sufficiently large, laminar flow fails to model the phenomena, which turns into "turbulent flow," phenomena that is beyond the reach of physics to explain, describe or control in a satisfactory way.

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 offered to "indicate the general character of the results to be expected in cases which are beyond our powers of calculation." (562.)

Only after much 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 a higher requirement 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 increases; and the more you buy over the limit the faster the price increases. That is, turbulent flow requires a wastage of energy that is like a higher price, which is needed 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 quite quickly. The control variable (pressure) moves the system through both the laminar range and the turbulent range.

The culminating example of such control variables is taken from metallurgy, specifically the making of steel. 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 controlling variable is a ***transformation speed***. A slow transformation speed produces pearlite; the transformation is continuous and controlled by quasi-static processes. A fast transformation speed produces martensite; the transformation is discontinuous and outside the reach of platonic science. 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.

Investigations in materials science shows that useful metals have a crystalline character; spatial symmetries of crystals make them adaptable to methods of platonism. Each specific material or combination of materials also has unique properties that limit applications of platonic methods. Production of steel illustrates both successes of platonic science and also its shortcomings.

Common 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 have a form that is called "face-centered" and the alloy is called ***austenite***. When the temperature is lower than 1333 °F, the form of the crystals is called "body-centered" and the alloy can have different detailed forms and names depending on the "heat treatment" or production process.

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.

If austenite with 0.83% carbon is slowly cooled, e.g., inside a furnace where the temperature is strictly controlled, the result is called ***pearlite***. If such austenite is suddenly quenched, e.g., by being thrust into a large vat of ice water, the result is called ***martensite***. Important differences between the processes are shown by differences between the final products. Pearlite is softer and more workable while martensite is harder and more brittle. Pearlite is made up of layers of two different components that produce a shimmering appearance like that inside an oyster. Martensite is uniform and has a duller appearance.

The transition from austenite to pearlite is a continuous transition and can be well-modeled by the diffusion equation, a linear form. In contrast, the transition from austenite to martensite is a discontinuous transition and has no such model.

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. There is sufficient space inside face-centered iron crystals for carbon nuclei to move around. However, carbon nuclei do not fit inside the body-centered form. If hot 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 1333 °F transition temperature, iron nuclei are easily shifted and 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 carbide particles grow and link up to form layers. This is the quasi-static formation process of pearlite.

The formation process of martensite is very different. Sudden quenching causes the material to undergo fast powerful changes. Hence, the martensitic transition is more difficult to trace then the slower pearlite formation process. Imagery suggests sharp discontinuities. Sudden quenching cools the surface first and a "changing temperature front" moves inward, supposing that the phrase "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. The material undergoes pervasive distortions in tight but unorganized wrenching and pulling and squeezing. Often a high-energy sound wave is emitted that resembles clicks or a scream. All details change abruptly, constrained only by collective bonds that hold the material together. 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.

Steel-making shows aspects of nature that are partially adaptable to platonic science when processes lead to formation of pearlite but where the adaptations fail during the formation of martensite. Generalizing from the examples, forms of platonic science are based on linear forms by means of which fine movements can be continuously controlled through "quasi-static" methods, as in the making of pearlite. Such linear forms and quasi-static methods fail to adapt to more powerful activity that occurs during the making of martensite. Similar partial adaptations and failures appear in the transition from laminar flow to turbulence in water flow and in the transition from high fidelity to noise in audio circuits.

f. Laws of physics fail to track or control discontinuous transformations of water vapor into diverse crystalline snowflakes.

Discontinuous transformations in steel-making show non-platonic aspects that become even more emphatic in processes that generate 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 generates an enormous multitude of symmetrical forms; but, even under the most advantageous laboratory conditions, details are beyond understanding and transformations can only be partially understood or 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 publication on my websites, "Facts about snowflakes," I used Libbrecht's publications to show the failure of platonic science to account for the generation of snowflakes. http://www.quadnets.com/testimony/snowflakes.html I take a different path here.

On his website, Libbrecht's images, copied below, show two stages of growth of a single ice crystal prepared in the 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. A single pattern is repeated six times in 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 of them follow almost exactly the same set of variations. How is this possible?

Here's what Libbrecht says in response to the question:

> "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."
> http://www.its.caltech.edu/~atomic/snowcrystals/faqs/faqs.htm

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.

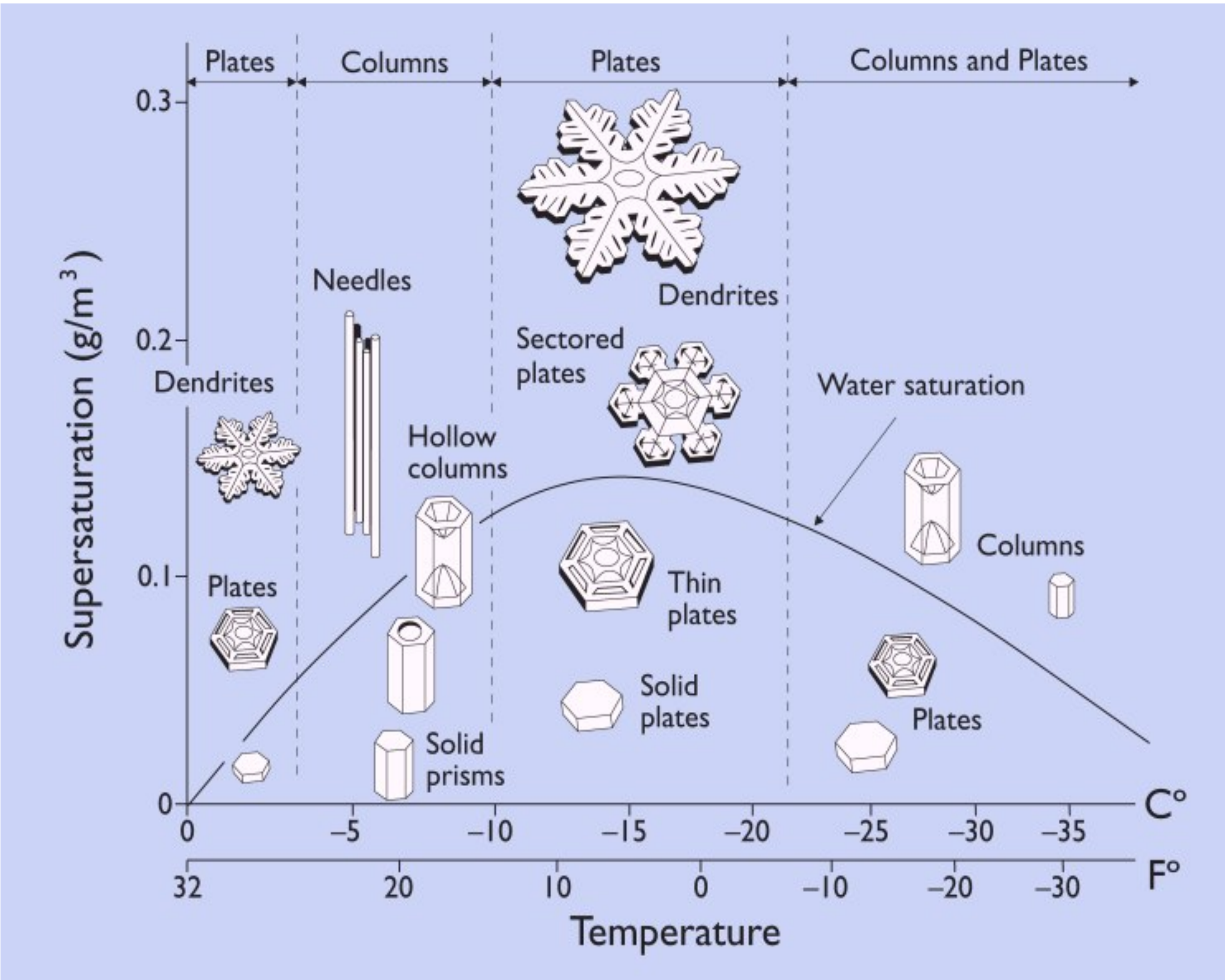
Suppose that that each arm or branch can take on any of the possible shapes with equal and independent likelihood, a supposition based on the "fundamental hypothesis of equal *a priori* probabilities" of statistical mechanics. (Tolman 59, 350.) If there are 10 possible shapes, the probability of a snowflake having all branches with the same shape is then 10^{-5}. (The choice for the first branch is arbitrary but then all other five branches must independently conform.) Applying platonic principles and a probabilistic model, I estimate that the chance of producing a 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. But my understanding is that, while incomplete snowflakes are common, just as Libbrecht states, such "hybrid snowflakes" are rarer or non-existent. (See http://mynasa.nasa.gov/pdf/183516main_nakaya.pdf for NASA's version of Nakaya's snowflake classification system.)

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

I suggest, contrary to Libbrecht's assurances, that the generation of snowflakes is an exemplar of phenomena that are outside the reach of platonic science. As a speculation, I would suggest that there might be an influence or "force" that stretches across the whole snowflake and that integrates the growth. Such a large-scale 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 platonic science are shown by detailed snowflake phenomena organized in the "Nakaya diagram" shown below, in a standard version copied from Libbrecht's website.

The Nakaya diagram 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 temperature below freezing, or superfreezing, and excess water in the air, or supersaturation. Water vapor, even in saturated air, is transparent; excess water vapor in supersaturated air is cloudy or foggy. Supersaturation in the diagram is measured with respect to ice; different values shown by means of the "Water saturation" line refer to excess water vapor with respect to supercooled liquid water.



Conditions for producing snow can be compared with thermodynamic equilibrium, previously discussed. Equilibrium means an isolated system, quite different from a cloud. To get to equilibrium, the container is closed; equilibrium vapor amounts to 100% humidity. Supersaturation is impossible; any excess water vapor results in condensation. Nor is superfreezing possible in an equilibrium system. 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. There is nothing but water in involved in the process. 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-right-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 forming from vapor have shapes like small plates or prisms.

Moving away from the equilibrium point at the lower-right-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 generated 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 generate dendrite snowflakes that cannot be generated under equilibrium conditions or by means of quasi-static processes. The distinct and separated snowflake symmetries that are the focus of our inquiry come about by reason of discontinuous transformations. There is a complete change of form that occurs abruptly when compared to equilibrium processes. Although we can generate and observe such discontinuous transformations, they are not within reach of our scientific models.

I suggest that the supposed Laws of Thermodynamics fail to provide insight or controls. Indeed, said Laws fail to apply to most of the phenomena of actual life. As a particular example, the "Laws of Thermodynamics" invented by Clausius fail 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 violates the Laws, causing a continual. unbounded "increase in entropy" — but, of course, fuel and ice must be continually added. Clausius' First Law applies only where energy is constant.

Clausius' Second Law applies only where entropy tends toward a maximum. Neither of those statements is true for a system with a maintained temperature gradient such as a fire poker. 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 develop the principles that Clausius and other founders had propounded. The results fail to cohere. In an earlier version of my views, "A Patchwork Of Limits: Physics Viewed From an Indirect Approach" (2000), I quoted 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 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 a system at equilibrium is disturbed by a small amount, the various parts of the system adjust so as to return it to equilibrium. Adjustments are tracked by thermodynamic variables like p, V, T, n (e.g., 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 a "process" until they become substantial. The First Law works for systems that belong to a certain class where 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 systems." The Ideal Gas Law defines such a conservative system and was the system that Clausius used to develop and construct his system. For the Ideal Gas, $dU = (3/2)\times R\times T$ and $dU = T\times dS - p\times dV$ because all processes are reversible.

The First Law of Thermodynamics incorporates the familiar linear form 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 possible processes is generated by the "proportionals" p, μ (chemical potential) and J, which show continuing application of Pythagorean principles.

Strict applications of the First Law are limited to activities where an equilibrium point is moved. It tracks movements of the system from one equilibrium point to another equilibrium point. The First Law applies only to a system where values at a final equilibrium point are the same regardless of the initial equilibrium point. The final equilibrium point must be invariant regardless of the process that moves the system from an initial equilibrium point to the final equilibrium point. This is a very limited class of systems.

The problem with trying to apply this construction to snowflake generation is that there are 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 condition 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 snowflakes. Platonic principles of invariance and symmetry cannot provide assistance in tracing the generation and development of 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 the Clausius construction, entropy S is assumed and temperature T "pops out" of mathematics that develop the assumption.] Reversible adjustments are always in the form of reversions and relaxations. The Second Law prohibits the kind of excitatory activity that leads to reversions and relaxations but mandates reversions and relaxations that nullify such excitatory activity. The Second Law mandates quietude because only in quietude can "entropy" be exactly defined.

On the other hand, in actual life, there are many "irreversible" processes where neither the process nor a temperature can be exactly defined. Physicists' advanced constructions based on platonic principles suggest definitions for temperature under some situations that lead to 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***. Using words metaphorically, I suggest that this is the “same” premium or additional expenditure of energy that leads to the individuality of snowflakes. Advanced constructions of platonic science suggest that some of the “dissipated heat” or “produced entropy” goes into individuality. (Prigogine & Stengers, 267-290.) In sum, it appears that dissipation and irreversible processes are the basis of individualized snowflake production.

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.)

Suppose that snowflake production is part of a cyclical process: a finished snowflake condensed onto a particular dust particle is subjected to a rise in temperature causing the snowflake to evaporate; then the temperature falls again. Either no snowflake will condense on the same dust particle during the repetition or perhaps a different snowflake will be produced. My sarcastic “far-from-equilibrium” version of the Second Law says that you can’t make the same snowflake twice, you can’t run the same race twice, you can’t try the same case twice. Heraclitus’ version was that you can’t step into the same river twice. My sarcastic version of the Second Law denies rather than confirms the controlling power of invariance, the center of the “definition of science” according to de Santillana, discussed above.

The Laws of Thermodynamics would prohibit the individualized character of snowflakes. There is no quasi-static path that connects supersaturated water vapor to superfrozen ice crystals. Unlike an equilibrium system where the final state is invariant, there are a multitude of possible final states. Platonic science cannot handle such facts. The only explanation of platonic science for the astonishing and beautiful symmetries of snowflakes is that stated by Libbrecht: "nothing."

5. Actual life does not fit into spatial forms of platonic science. In new constructions, muscular movements of actual life are modeled by temporal forms, including forms that control race contests in sports arenas and jury trials in courtrooms. Outcomes of such events turn on personal efforts and personal decisions that occur during transformational critical moments.

The foregoing reconstruction of the "modern scientific view" shows that it is based on a compact set of spatial forms and on successes in applying those forms to certain phenomena, e.g., spheres moving solely under the influence of gravity in empty space and pV=RT relations of a dilute gas in a closed container. Platonic forms have been successfully extended to electricity and magnetism and to other subject matters. Successful forms are embodied in wonderful technologies.

Such successes have encouraged a presumption that scientific forms describe and control all phenomena. The presumption has led to further successes but it has also limited development. Matters that fit easily into scientific forms are investigated and developed while non-conforming matters are disparaged and disregarded.

For some persons, successes of science and technology would 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 for Laws of Physics belittle freedom and consciousness. In actual life, however, personal disputes and other personal matters cannot be handled by reference to "impersonal invariants," much less 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 lives 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 activities of models to be built from new technologies will more closely resemble those of animals that have actual life.

a. The beat is a primal temporal form in proposed 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 construction of ancient Hebrew Thought and ancient Greek Thought, each Thought had a distinct character. In factual background, early Christians used diverse Jewish and Greek source materials in constructing the religion; scholars concerned with Christian origins have divergent views about the sources' natures and influences. (*Id*., 20-21; Schweitzer, Preface; 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 have references in 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.

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 into variant beat forms. Variant beat forms 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*ʻ there is originally something violent." Compared to other words, "*regha*ʻ 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*ʻ 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 will be transformational but there will also be conserved a substance that carries the characteristics of the original. 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 my constructions. 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*ʻ 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. That is, in actual life, jumpy, abrupt, even violent action is often a more powerful influence than smooth action based on reason — and such power is based on the suddenness and size of the jumps.

A further 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 so 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, even 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 active 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 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. The beat generates muscle-like activation in device designs that are part of new proposed technologies.

My constructions incorporate materials taken from theories of Piaget, Nietzsche, ancient Greeks and physicists that have been discussed above, with appropriate modifications. Materials from biological sciences are also incorporated but greatly simplified. Novel aspects are illuminated by Boman's review of Hebrew Thought that contrasts movement and action with rest and states.

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

In proposed technologies – Quad Nets and timing devices – internal signals embody ***forms of action*** in contrast to signals in computer systems that embody ***forms of state***. 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 muscular movements. In plane geometry, a student uses mental imagery of a spatial form of a triangle to control his chalkboard construction of a triangular figure.

As introduced above in §1 b, primal action herein is ***repetitive muscular movement***. A primal temporal form is ***the beat***. A person ***follows*** the beat through repetitive muscular movements. In effect, the beat controls such movements because the person makes such movements in accordance with the beat.

Tapping feet of musicians are examples of a beat that controls repetitive muscular movements. Whether the connection between ear and foot is innate or socially acquired, facts show a widespread and common form of 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 19^{th} century forms of discipline. The concertmaster had a foot that could not resist tapping, sometimes for several measures at a stretch.

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. 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 brain and confirming or modifying that self-generated beat according to the drummer's beat. (For more details, please see the formal paper "An Ear for Pythagorean Harmonics" available on the website.)

The principal construction herein commences with the beat. The beat appears in an imaginary domain like that of a geometrical construction or chalkboard diagram by a physicist. The domain is populated by devices proposed in new technologies. It is also a construction that connects to actual experience. I suggest that you have your own experience of beats and can connect operations of devices like A Dogtail for Wagging to such experience. A general design goal in the new technologies is to establish connections between device operations and a person's experience. Sometimes such connections can be made strong and sometimes they are no more than weak or only speculative — but the goal remains.

I suggest that something like beats drive repetitive movements in actual life, e.g., repetitive movements that are self-perpetuating like the sucking of a 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 beast. 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, or blunt and self-absorbed, in another situation.

The beat is self-perpetuating. The beat generates movements and the beat is in the movements. Movements of actual life come from the beat. Without movements of actual life, there are no actual objects and there is no basis for sensory objects or purely mental objects. Spatial distance is measured according to stepping on the beat. The beat is the source of rhythms of action and of appetites and impulses that lead to action. Sensations, objects, emotions, desires, drives and action: all come out of 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 desires and drives and 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 construction resembles Nietzsche's and Plato's, only mine is based on muscular movements and on "the beat" that leads to models of muscular movements. Common methods of construction operate on subject matters of psychological 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 a hegemony of will to power based on drives and Plato declared a 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 might ***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 words, in my constructions, muscular movements are controlled components, rather than controlling components. In an important particular class of constructions, muscular movements are controlled primarily by the beat and secondarily by other objects. A person can exercise specific secondary control through insight, training or use of imagery of forms. A person's primary activation of muscular movements is controlled by the beat and yet the person secondarily exercises freedom with respect to specific objects when choosing particular muscular movements. The moment arrives for the jazz violinist to improvise and she does improvise, but the exact selection of notes is "up for grabs." The violinist can improvise on a phrase just played by the saxophonist, return to one of her own previous phrases or do something else that is quite different. Similarly, as discussed below, a baseball player at batting practice trains his skills as the pitching machine rhythmically throws ball after ball. A quality control inspector in a factory rhythmically examines manufactured items appearing on a conveyor belt and pulls out those that fail to conform to standards, exercising judgment and skill.

In simple constructions, the beat has controlling power. The tempi of all repetitive movements follow that of the beat, changing when the beat changes. In device designs, the beat is a stream of pulses that other pulse streams follow. The beat makes things happen. In actual life, obvious examples are dancing or marching according to a beat. Members of a drill squad step together at a fixed rate. Musicians sing or perform on instruments according to a conductor's baton.

Music and marching show adaptations of the beat to platonic ideals of invariance and symmetry. Temporal invariance is established by means of uniformity of periods between beats. Symmetry among persons is established through a collective beat that is made up of individual beats in the minds of participants. Invariance and symmetry are established during symphony orchestra rehearsal and drill squad practice. A drill squad trains with a metronomic pace; a conductor's tempo is more fluid. Often a ground of unity is established at the outset by unison sounding of a tonic note or by unified marching in place.   Then variations and asymmetries can be introduced. Two musical themes engage in counterpoint. The drill squad splits into two parts that pass through each other and recombine in a different way.   The beat presides over all such counterpoint and maneuvers.

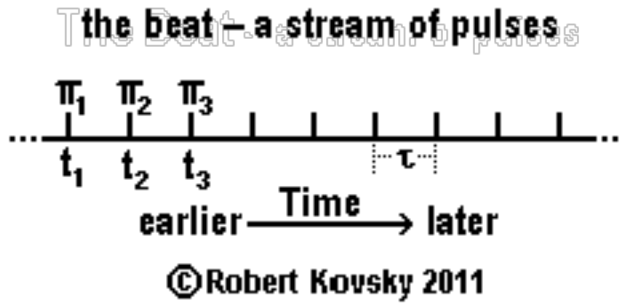
The chief present example of a beat in my device designs is the repetitive pulse generated by the ψ signal generator in An Eye for Sharp Contrast. Between any two ψ pulses, the system goes through one entire cycle, including a step-wise change in forces produced by muscle fibers that control focusing of the Lens. Each ψ pulse triggers the sequence of events that make up a cycle. If ψ slows, all other cycling activities in the Eye are slowed. As shown below, the beat controls wagging movements in A Dogtail for Wagging.

Returning to the primal beat, repetitive movements alternate with ***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, except perhaps for varying durations, and neither movement nor rest exists without the other. Alternations of movement and rest make up the internal 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 concept: a strict and fixed uniformity amounts to metronomic or mechanical identity; or uniformity may be fluid and variable, *rubato* for musicians. The tempo expresses the character of the beat, perhaps tense and gradually speeding or perhaps relaxed and gradually slowing. 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. 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.



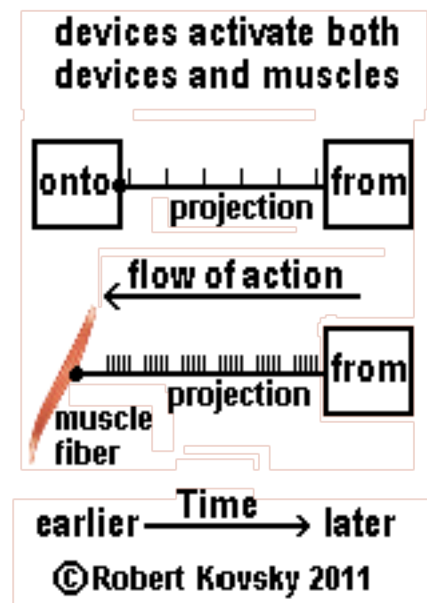
As shown in the Figure, the primal beat is made up of ***action pulses***. Each action pulse – π_i – occurs at a distinct instant t_j. A smaller number in the index (j) refers to an earlier time. There is uniform period – τ – between pulses.

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. In this essay, constructions are chiefly based on action pulses because of their simplicity. The constructions lead up to Quad Nets at the end. Action pulses in timing devices and Virtual Energy packets in Quad Nets are models of "action potentials" that appear in brain signals.

In new technologies, delays are operational controls. By putting delays into controls of devices, including unavoidable delay, time required for the movement of energy can be reduced to a minimum. Such movements become "instantaneous" in idealized timing device models. That is, in timing device models, 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.

As shown in hookups in the Figure below, movements of energy occur when action pulses travel from a timing device to a timing device or from a timing device to a ***muscle fiber device***. In constructions in this essay, the focus is on muscle fibers and muscle-like movements; assemblies of timing devices are discussed in other publications on my website. In the Figure below, the "flow of action" is from right to left to adapt to the form of spatialized time.

Timing devices and fibers are connected by ***projections***; each projection is a connection ***from*** a timing device ***onto*** a timing device or 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 indicated by dots in the Figure. A projection is a model of the axon of a biological neuron and a junction is a model of a synapse between such an axon and a receptive part of another cell.



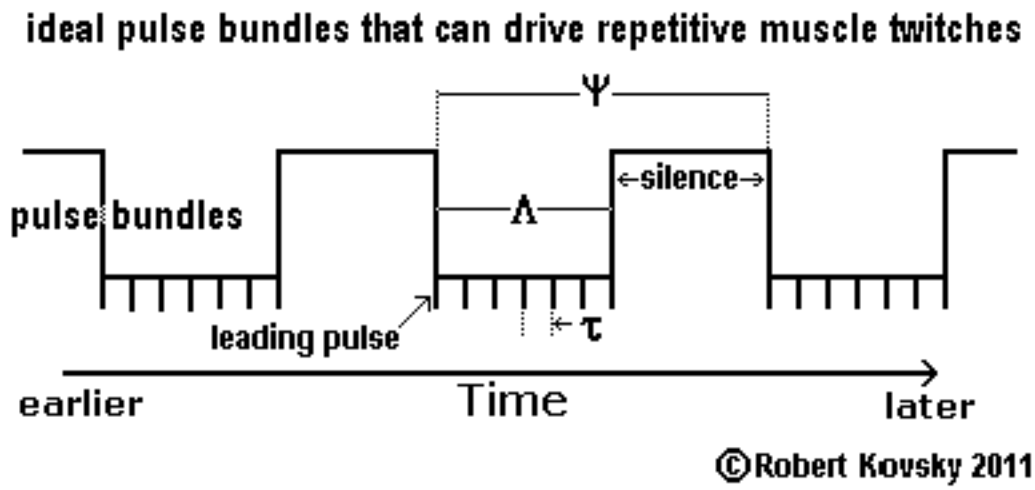
Of chief importance, and as shown in the adjacent Figure, movements of energy can occur in the form of ***pulse bundles*** that travel from a timing device to a muscle fiber device — the fiber device responds to pulse bundles by ***twitching***.

Twitches of muscle fibers are primal activity of my models of actual life. Each twitch is a contraction of a muscle fiber that can perform physical work. A muscle fiber maintains a twitch for a certain duration of time and then relaxes. In between twitches, the muscle fiber restores its energy reserves. In the constructions, twitches occur uniformly and repetitively according to repetitive pulse bundles, one twitch for each bundle.

The "muscle fiber" in my constructions is intended to model a "myofiber," the smallest unit of animal muscle. In constructions shown below, muscle fibers are organized in "muscle modules" that function like animal muscles.

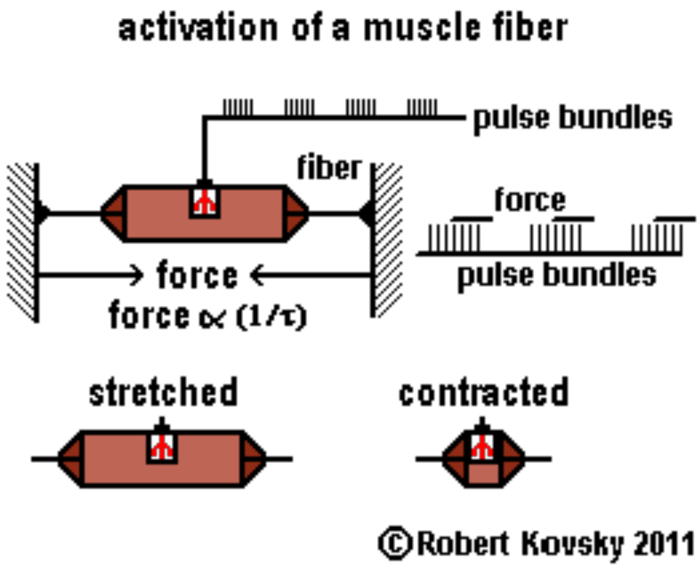
In the constructions, the single action pulses of the primal beat become leading pulses in pulse bundles. The leading pulse signals the arrival of the beat and is the initiating impulse that will start a twitch. Pulse bundles that drive twitches of muscle fibers are primal signals in constructions herein.

An idealized and invariant signal shown in the Figure below is made up of bundles of action pulses that are defined by three variables, namely, ψ, Λ and τ. The organizational period ψ sets the rate of uniform twitching. The durational period Λ controls how long each twitch lasts. The signal period τ controls the force of a twitch. In a stream of ideal invariant pulse bundles, all three variables are fixed and Λ/τ is an integer. The number of pulses in the bundle is $(\Lambda/\tau) + 1$. There is always at least one pulse in the bundle — the "leading pulse" that identifies the beat — even if Λ is very small.



I suggest that a bundle of action pulses resembles a "burst" of action potentials like that observed during operations of biological brains. Each bundle or burst drives one twitch of a muscle fiber (constructional) or myofiber (biological) to which it is delivered. Twitching can be defined by an invariance principle: repetitive uniform pulse bundles are directed to a muscle fiber that repetitively and uniformly twitches. 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 produced by a data-entry clerk or assembly-line worker.

The activity of a single muscle fiber being activated by a beat is shown in the Figure below. The period of twitching is ψ, the period of 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 part of the definition of the device. 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 length of a twitch is arbitrarily set equal to the durational period Λ shortened by one pulse period.



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; i.e., where 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 $\mathscr{k}$ is a coefficient that is the same for all τ.

In constructions herein, τ is fixed within each pulse bundle. (This constraint is required by limits of imagination. Actual devices could be varied experimentally.) There is, therefore, a frequency φ such that $\varphi = 1/\tau$ or $\mathcal{F} = \mathscr{k}\times\varphi$. In words: force increases linearly with frequency if the fiber is prevented from contracting.

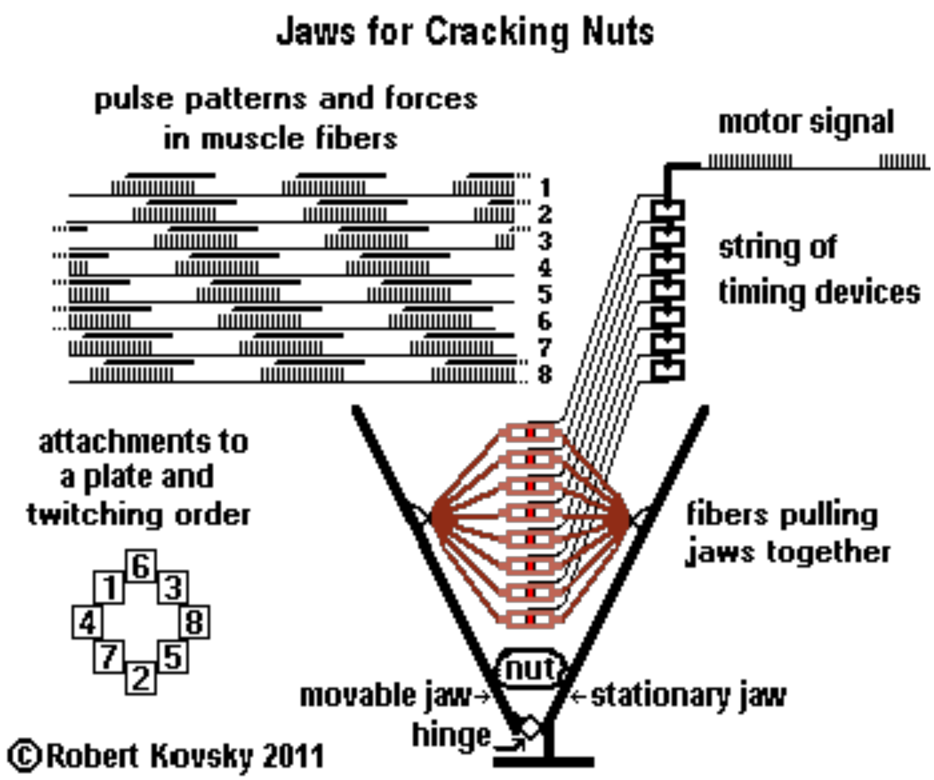
Suppose the fiber is allowed to contract. The question is whether a contracting or contracted fiber generates a force that is different from that of the attached and stretched fiber. To start off, the rule is that there is no difference. A twitching fiber generates the same force whether it is stretched 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. Each timing device interposes a time interval between receiving a pulse and discharging a pulse.

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***, that 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.)

Numbering of attachments to a plate refers to the sequential order of activation of fibers. Timings are adjusted so that 1follows 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.



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

Pulling of the jaws may take on a form of steadiness or invariance but any such steadiness or invariance is a specific condition achieved through a specific kind of operation. Such steadiness or invariance is not an inherent basis of all operations. I suggest that these comments can be generalized to a larger scale of operations where larger kinds of steadiness and invariance are sought to be achieved.

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. In actual life, as in proposed device designs, steadiness is an achieved performance rather than inherent in the static nature of some underlying metaphysical "being." An organism that can hold one object steady with certain muscles while moving other objects with other muscles has a capacity to control its own actions and a capacity to attempt to control other bodies 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 symmetrical wagging movements controlled by a beat.

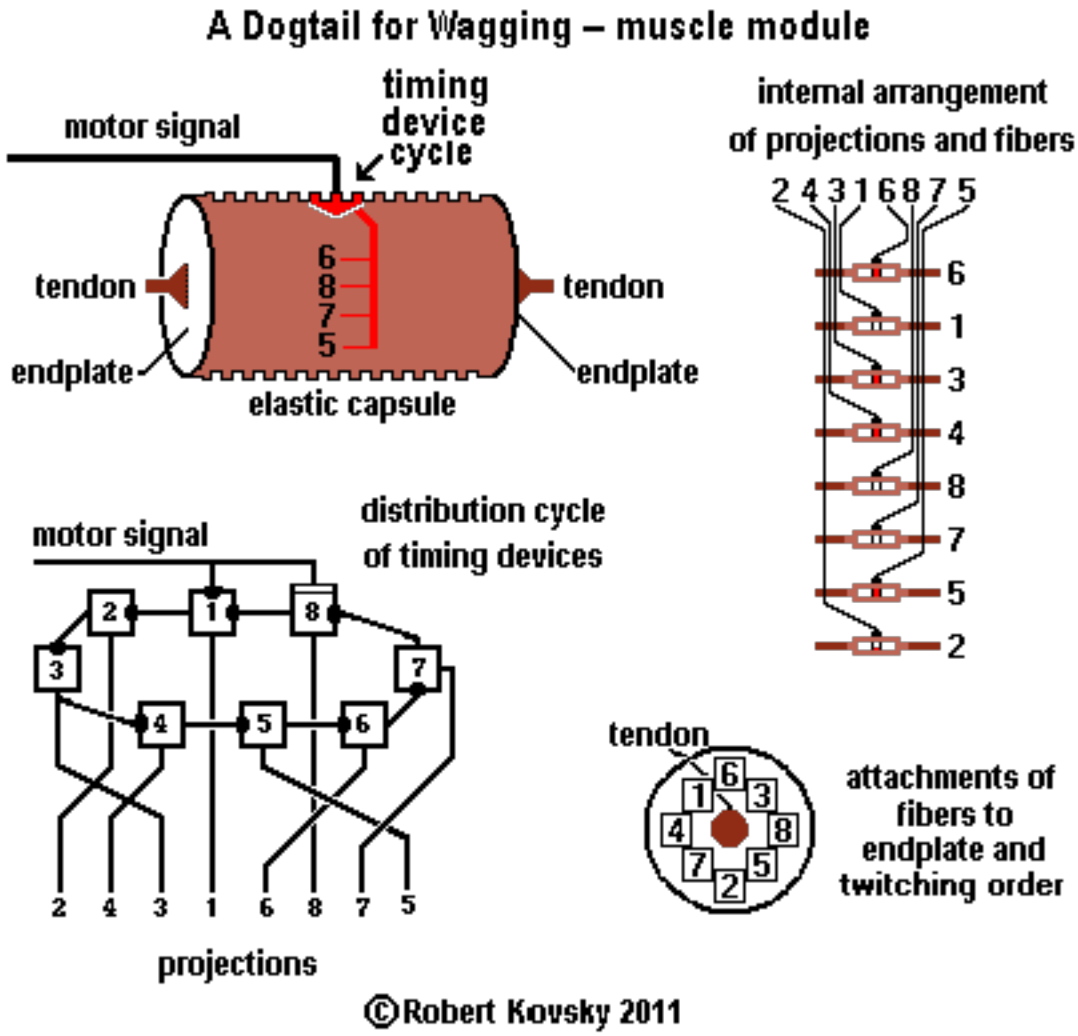
Muscular movements are goals of constructions – yet, the foregoing design of Jaws for Cracking Nuts does not involve movement. Although the forces on the nut can be varied, there is no suggestion that the forces move anything. Movement would occur if a nut were to be cracked. In such an event, forces between jaws must be suddenly reduced so that, after collapse of a nut, the jaws do not damage each other. Further 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, a timing device project published on my website, does involve muscle-like movements. Each ψ cycle, the force produced by muscle fibers squeezing the optical Lens becomes either stronger or weaker, through an incremental step. As a result, the Lens changes shape and gets either one step stronger or one step weaker in its 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 limited.

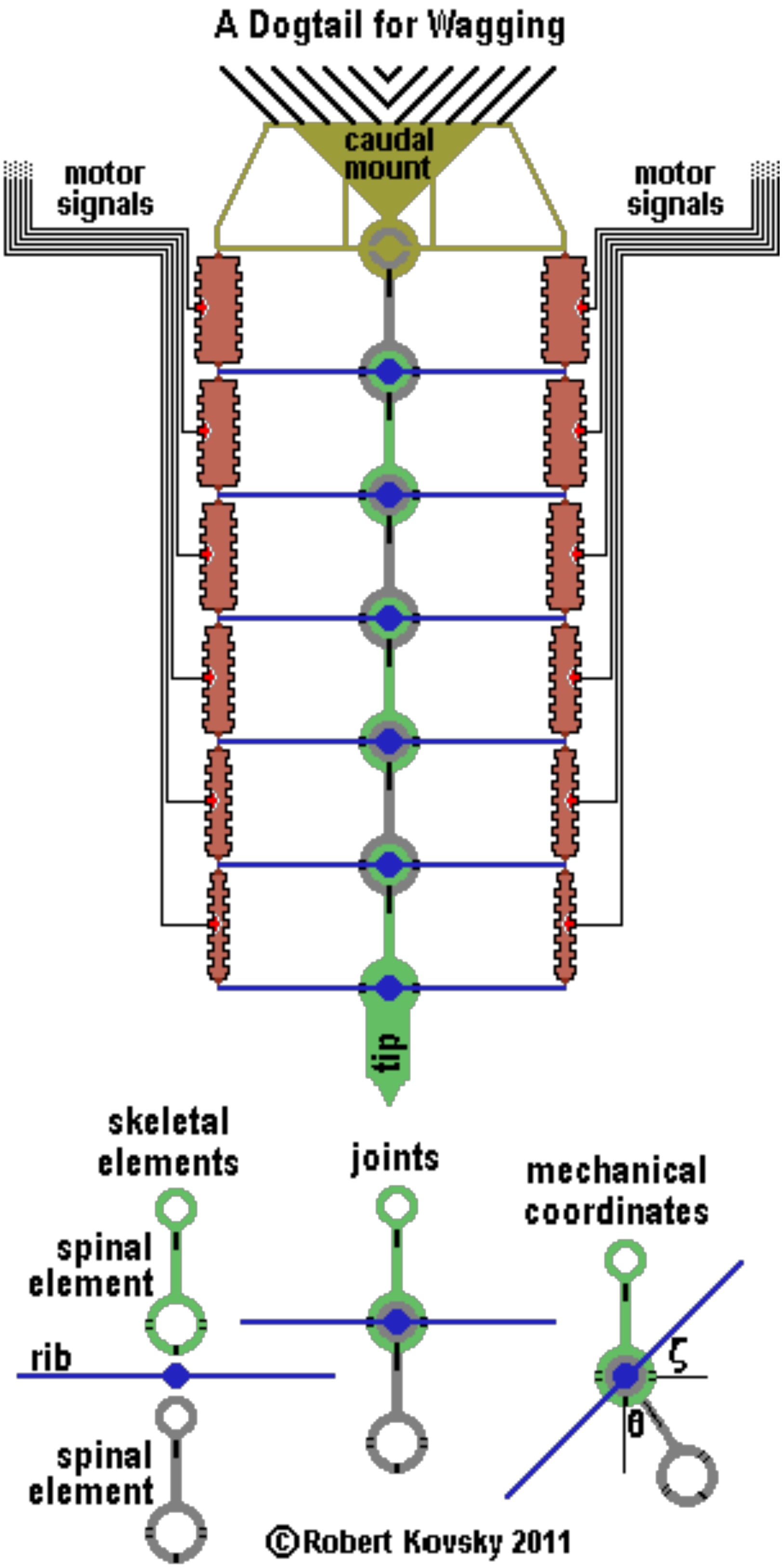
A Dogtail for Wagging, proposed herein, is a timing device design for production of classes of muscle-like movements, namely, quasi-static movements, continuous movements and jumpy movements. The construction path goes through several stages. Initial design are suitable for maintaining static positions but are not suitable for movements or for performance of work. The next stage of development, the actual Dogtail design, produces positioning movements, wagging movements and kicking movements but does not perform significant actual work.

Comparison of classes of Dogtail movements with the structure of classical mechanics shows that positioning movements are contained within that structure but that other classes of movements are excluded. e.g., because of dissipation and “non-holonomic constraints.” The exclusions would be even more significant were device designs to be further developed to perform actual work, e.g., as A Fishtail for Propulsion. Overall, the constructions show how forms of physics fail to describe or control muscular movements of organisms that have actual life.

The Figure below shows a muscle module for the Dogtail design. The module is developed from the design of Jaws for Cracking Nuts with some major modifications. Muscle fibers are enclosed within an ***elastic capsule***; the unit becomes a freestanding module connected by ***tendons*** to other components. Also, the distributive hookup of timing devices is closed into a ***cycle*** in which a pulse bundle circulates, repetitively activating fibers inside the capsule. (Strictly, the number of devices in the cycle of timing devices must exceed ψ/τ; interstitial devices can be used but are omitted in the Figure.) The cycle of timing devices is part of the module design, a feature that is different from what is seen in biological organisms. During operations, a new pulse bundle carried on the motor signal line interrupts and replaces a circulating pulse bundle. The “gate normally open” timing device at position 8 in the timing device cycle carries out the interruption.



In sum, the muscle module is designed to produce approximately steady muscle-like forces. Alternatively, changing motor signals can produce changes in muscle-like forces, in a continuous ramping way, in incremental steps or in jumps.

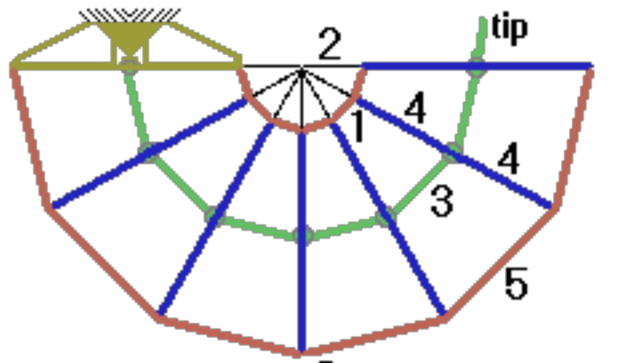


The design of A Dogtail for Wagging is shown in the adjacent Figure. Twelve muscle modules are attached in opposing pairs to a skeleton that has seven joint units. Each muscle module is controlled by a motor signal. The Dogtail is affixed to an immovable ***caudal mount*** at the first or lowest joint.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

The Figure shows rigid skeletal elements: ***spinal elements*** and ***ribs***. Two spinal elements and a rib element make up a joint unit with two joints. Within a joint unit, the smaller circular end of each spinal element has a thin cylindrical wall standing perpendicular to the page with ball bearing races on both sides, each race facing a matching race in another element. The two joints move independently and have two mechanical coordinates, θ and ζ, which track angular positions. (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 would mark 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 adjacent to elements in the 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 the length of 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 above. 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 also maintained by symmetrical motor streams that can vary from low volume streams of pulses to high volume streams. 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" are 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 and by slightly reducing the signal period τ. This causes the number of pulses in right side bundles to increase by one, leading to a small 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.

We thus return to the question of force versus length of muscle fiber noted above. This construction investigates two different ways to modify the force of muscle models according to their 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." A comparison between operational features of the two models shows that dissipation modeling is more like what happens in actual life. Models can also combine elastic modeling and dissipation modeling.

Start both models with the force relation introduced above in connection with activation of a muscle fiber, namely, $\mathcal{F} = \mathscr{k}/\tau$ or $\mathcal{F} = \mathscr{k}\times\varphi$ for ideal pulse bundles. Principles of symmetry support generalization of the force relation so that it also applies to a steady force produced by a muscle module; let $F=k\varphi$ represent such a steady force. 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, although the steadiness of F is approximate and may depend on circumstances. The coefficients are also different.

Let L denote the length of the elastic capsule, a variable quantity that is defined during production of a steady force. Let L_0 be the minimal length, 1 unit in the above design. Similarly, let L_1 be the maximal length, 5 units in that design.

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

In elastic modeling, the 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 physical model, a muscle module has 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 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 positions and a compact class of diverse shapes.

Formally, a system of equations 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, equivalent, of 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 fiber is stretched, thus increasing the strength of a stretched fiber, dissipation modeling imposes a reduction of strength of a contracted fiber. Strength or energy is simply wasted or dissipated. $F = k\varphi - j(L_1 - L)$.

Reiterate the previous procedure to investigate dissipation modeling. Suppose the Dogtail is engaged in centerpoint activity and that then motor signal changes occur that increase contractile forces on the right side. The Dogtail bends to the right. As it does so, contracting right-side modules lose strength and stretching left-side modules gain strength. These changes reduce the forces that cause movement. When greater dissipation balances force changes resulting from the decrease in τ, movement of the system ceases.

Obviously, a single mathematical form of force relation is common to the two models. It is a linear relation with two variables, φ and a length difference that is similarly defined 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, 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 opposing muscles. 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 will "spring" into action. A stationary system will start quivering. It appears that an elastic system will contain conserved energy that can interfere with operations.

The dissipation model does not present such questions. The only "conservative" operations in dissipation modeling occur when a muscle fiber is fully stretched and dissipation is close to zero. It is impossible for both opposing muscle modules to be fully stretched. Hence, energy is always being dissipated. With fixed motor signals, a Dogtail "settles down" or relaxes into a fixed position.

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 even to combine elastic and dissipation modeling, e.g., $F = k\varphi + \hat{j}(L - L_0) - j'(L_1 - L)^2$.

It is also possible to combine the two models conceptually. The elastic capsule provides convenient imagery of physical balancing within the muscle module that supports subsequent balancing constructions. The concept of dissipation avoids imagery of quivering.

For purposes here, I use linear dissipation modeling $F = k\varphi - j(L_1 - L)$. It appears that, like elastic modeling, the dissipation model establishes 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 fixed shapes of the Dogtail are the base for investigations into its movements. As shown below, the base is sufficient to describe some movements but not other movements. A similar distinction is observed when forms of classical mechanics are applied to movements of the Dogtail: the scope of forms of mechanics includes investigation of movements based on fixed shapes and fixed cycling bundles but the scope of such forms excludes investigations into more highly activated movements, such as kicking movements. The distinction between included and excluded mechanical matters is parallel to the distinction set forth above in connection with thermodynamics between equilibrium states and quasi-static processes, on the one hand, and discontinuous transformations, on the other hand. In both classical thermodynamics and classical mechanics, the base of development is restricted to fixed systems in which basic temporal forms are invariant or step-wise incremental.

The Dogtail is designed to produce three classes of movements: (1) positioning movements, (2) wagging movements and (3) kicking movements. These generally correspond to 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 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 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. In sum, positioning movements are predictable and controllable incremental changes in shape resulting from incremental changes in step-wise constant patterns of cycling pulse bundles.

Positioning movements can be described using terms similar to those used by kinesiologists to describe some 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 with 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 that changes in forces are completed within a single cycle of operations, even before the start of substantial actual movement. Because the highly activated signal is going into a stretched muscle module, there is little dissipation and the produced force is higher than it was on the contracted side. Meanwhile, the lowest level signal into the contracted side is reduced even further by high dissipation and produces scant opposition to sudden forces produced on other side. The result is 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 but I suggest that a suitable Dogtail design could produce a class of controllable wagging movements.

I suggest 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, as in the ballistic movement of a golf swing where "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.

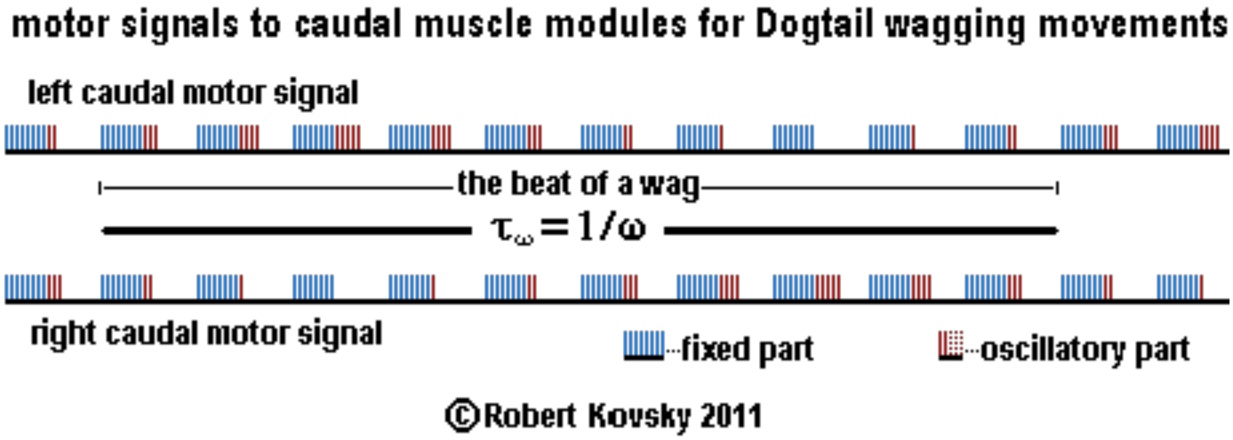
That is, the description of sports movements suggests a path for construction of wagging movements of the Dogtail. Begin with a centerpoint fixation that is maintained by symmetric opposing patterns of pulse bundles directed at muscle modules. Following Cooper, superimpose on such fixation a movement 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.

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 are still moving to the right while the caudal joint has begun moving to the left. The character of the 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 a simplified example of motor signals to the 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 of a wag.



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 is a hegemonic pulse pattern that organizes and controls the other pulse patterns.

The Dogtail construction is a proposed mechanical system that can be investigated by mathematical methods of classical mechanics, e.g., those stated in Goldstein, *Classical Mechanics* (1950). Developers of computational robotics have carried out similar investigations.

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 often 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 classes of systems with defined parts that move with respect to each other. Such systems are constructed in imaginary domains governed by "Laws of Physics" that operate like rules in a game. Parts are defined in terms of particles, rigid bodies or deformable bodies subject to force rules such as the force rule for muscle modules. Parts in 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." (10.)

Goldstein's construction begins by a restriction that the system be at overall rest with respect to the observer. (5.) This leads to: "Suppose the system is in equilibrium, i.e., the total force of each particle vanishes…" (14.) That is, applied forces and forces of constraints add up to zero for each and every particle in the system. As in classical thermodynamics, the construction starts with equilibrium, a condition of overall rest. 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 other words, 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 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 come 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 is 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. As for the first restriction, wagging movements are not based in equilibrium. On the contrary, at all times during wagging, parts of the Dogtail carry momentum; the momentum of each part is increasing or decreasing. Work is being done on and by the Dogtail; energy is being dissipated in varying amounts. Steady wagging movements driven by continuously cycling motor signals are outside the class of "equilibrium-based" movements and show that the class of such movements is narrow and has only limited applications.

The second restriction requires that "the virtual work of the forces of constraint is zero." The forces of constraint are produced by the muscle modules. During wagging movements, muscle 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 third 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. There is something along this line: the force equation for muscle modules depends on length of modules and on motor signals; and lengths of modules are based on positions of anatomical elements. However, 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 changes ω to change wagging movements. In terms of system control, motor signals are ***independent coordinates***. Motor signals are independent of the position or movement of the Dogtail and motor signals control wagging movements of the Dogtail.

Suppose the Dogtail were to be developed into A Fishtail for Propulsion. The muscular design of an 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 run between skeletal members as in dogtails; 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 in solid blocs of muscle, structures that can be dissected at the dinner table.

Suppose A Fishtail for Propulsion were to be designed that would accommodate these features. 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 force 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.)

d. Sports contests and civil trials illustrate partial adaptations of strife to symmetry and invariance, leading to balancing forms that climax in critical moments of personal effort and overtaking during footraces and in critical moments of personal decision by judges and juries.

In further constructions, § 6 presents device designs that lead towards Shimmering Sensitivity. This sub-section offers a broader and more speculative view of new forms of thought. Temporal forms incorporating invariance, symmetry and change often guide activities of institutions such as courts that control actual lives.

Further development starts with 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***. Device designs employ levels of activation: (1) quasi-static activation, (2) continuous activation and (3) saccadic activation. Quasi-static activation produces positioning movements; continuous activation produces wagging movements; and saccadic activation produces kicking movements.

Development leads to a fourth level of activation, ***shimmering activation***. Saccadic activation generates jumpy signals while more highly developed shimmering activation generates jumpy signals with choices that are constrained by forms. "Saccade" is a technical term for "jump." The word "saccadic" is applied to jumpy movements of human eyes and saccadic activation models such movements. Discussion of forms makes up much of the substance of this essay.

Different levels of activation denote the ways that signals change, with higher activation denoting faster changes and more variability. Conversely, as activation is lowered, signals and movements have stronger stability and movements can be performed with greater force. All activations can generate motor signals that have high volumes of pulses, e.g., centerpoint positioning with all muscles operating at maximum forces and maximal motor signals. What is different between levels of activation is the kind of change in signal. Signals change slowly and least frequently when activation is quasi-static and signals are being continually churned when activation is shimmering.

Some devices operate with only one kind of activation or with a subset of activations. E.g., forearm muscles can hold, squeeze and punch but they do not shimmer, although violinists come close with variable oscillations of vibrato and tremolo. Other devices, however, might operate with all the activations.

In anticipated designs, a single device system operates with all levels of activation. Suppose such a device system begins with shimmering activation, making delicate selections on the basis of multiple influences. The process proceeds to convert or transform selections into muscular movements that are performed with saccadic activation or continuous activation. 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 a strong, steady force. Carpenters driving screws, cooks slicing vegetables, piano players and touch typists all employ something similar.

I suggest that a process that chooses with purposeful but delicate sensitivity and that converts or transforms the choice into strong muscular movements might be the central actor in a device model of an "act of free will." The puzzle would be to set such a device model to a suitable task in a suitable environment.

Wagging movements require more changes in pulsing activity than do quasi-static movements. At an extreme of low activation, quasi-static adjustments to positions of the Dogtail can be carried out one joint at a time. Saccadic movements require more changes than continuous movements. Shimmering operations require the most changes but changes are balanced and organized through multiple forms so that resulting choices can be expressed with delicate movements, e.g., of a pencil.

Each level of activation generates distinct temporal forms of motor signal that produce distinct classes of muscle-like movements. Compare sitting and walking and jumping, especially if you imagine big jumps like a grasshopper. Activity controlled by shimmering activation is often more refined, e.g., balancing on a beam in a gym, threading a needle or tuning a violin.

Motor signals generated through quasi-static activation, as discussed previously, are steady or nearly so, based on repetitive pulse bundles in motor signals or repetitive bundles 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. Incremental changes in signals correspond directly to incremental changes in shape.

Continuous activation generates motor signals that are always changing in a uniform way. A certain content is sustained while cycling changes are ongoing. Imagery suggests oscillations and waves. In simple constructions, movement is controlled by a hegemonic beat. Dogtail wagging movements can vary from slow, low-amplitude movements to fast high-amplitude movements. The motor signal variable that controls speed and amplitude, ω – the frequency of the beat – is like the volume control of an audio amplifier or a pressure controller on a water pipe.

Saccadic activation generates jumpy motor signals and produces jumpy movements. Such movements can have many different forms, e.g., the "cock and kick" form used by the Dogtail. In my approach, the concept of jumpy movements is used to collect very different or ***disparate*** kinds of activities and a broad concept is used. In other words, diverse kinds of phenomena can be described in terms of jumps: the collection turns into a grab-bag and a hodgepodge.

Previously discussed ballistic sports movements such as throwing are saccadic. Hockey and basketball players are skilled in sudden movements. Moving between academic marks (A, B, C, D or F) or grade levels (3rd grade, 4th grade) is jumpy. Similar jumps occur between grades of manufactured products (Good, Better, Best). In the United States, legal status changes in a jumpy way on a person's 18th birthday. Moving one's personal residence is saccadic. Changes in employment or in close family membership are saccadic. Surprises are saccadic.

When two jumps occur in close proximity in time and space, they are said to be ***juxtaposed***. Often, one jump will follow another jump and the two juxtaposed jumps amount to a single jump, at least conceptually: 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. Repeated jumps sum to one big jump. A connected sequence of jumps or steps can make up a ***course of action*** that can be repeated. Often, a course of action has a purpose or goal. This sub-section explores such purposeful courses of action, e.g., footraces in sports arenas and trials in courts.

The composition of jumps into a course of action resembles previous constructions where a number of action pulses were combined to make up a pulse bundle and where a number of muscle fibers were combined to make up a muscle module. The construct as a whole has a function that is additional to and different from the functions of its constituent parts. What is new with jumps is that the composition can combine disparate elements, jumps of different kinds.

The path of development looks for ways to generate motor signals that actually produce muscular movements of bodily masses. A design goal is that muscle-like movements produced by composed jumpy motor signals are correspondingly composed. That is, suppose controlling motor signals first jump from a to b and then jump from b to c. This amounts to a jump from a to c. Design goals are for muscle-like movements produced by the motor signals to jump from A to B to C and for this activity to amount to a jump from A to C.

The foregoing construction leads to a structure of activity that is represented by a ***mathematical group*** in both body and mind. In actual life, brains control muscular movements in group-like ways, e.g., in games like checkers and hopscotch.

There may be multiple ways to juxtapose and compose jumps. Organized saccadic movements, like those in eyes, jump within a range of motion and are said to be "mobile." Such movements of eyes form something like a mathematical group, although confined to a range of motion. These features make jumpy movements useful during exercises of freedom, e.g., while considering multiple possibilities. A person can look all around and get everything into place in his or her mind.

Jumpy performance is often riskier than continuous performance. One jump may be incomplete when another jump starts. Some jumps end in landings that may not succeed. The concept of success/failure applies to jumpy action with greater importance than with other movements. If timings, directions and sizes of jumps are varied in a jumpy fashion, the resulting movements may be unpredictable.

Some saccadic movements, e.g., the cocking and kicking movement of the Dogtail, use a two-step or two-phase process. Activity in the first phase establishes and maintains 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 as the second phase. The two-phase process can be developed into a process that has a preparation or anticipation phase followed by an execution phase. Such two-phase processes lead to shimmering processes.

The classes of movements and activations have certain relations among themselves. Each class has a distinct definition but they share limit points and overlap each other. A tight fixed position can start to wiggle and wag with a relatively small additional motor signal. Alternating kick movements can be oscillatory if they start from and end in mirror-image fixed positions,. Positioning movements can be approximated by tiny little kicks. Shimmering activation is a kind of saccadic activation but it also generates continuous and quasi-static processes.

I suggest that the four classes of activations and movements are parts of a larger ***repertoire of activations and movements***. The repertoire includes activations and movements that are additional to the specific classes. The concept of repertoire can also be applied more generally, e.g., to a person's language skills.

In further constructions, ***balancing forms*** are used to control movements. Several classes of forms are used to control movements; balancing forms are of major importance. Four kinds of balancing forms are: (1) ***static balancing forms*** that control positioning movements produced by static activation; (2) ***oscillatory balancing forms*** that control movements similar to wagging that are produced by continuous activation; (3) ***saccadic balancing forms*** that generate and control jumping and kicking movements that are produced by saccadic activation; and (4) ***shimmering balancing forms*** that are generated by shimmering activation and that control or select possible movements to fit and maintain a balancing form defined by symmetry.

Static balancing is balancing without movement. In actual life, static balancing is maintained when standing on a fixed surface – changes in tension maintain the position with no movements or with small "virtual movements." A biological counterpart is in the eye, when muscular balancing maintains a fixed opening in the pupil. In modeling, static balancing is a special case of continuous balancing.

Oscillatory balancing is maintained by means of a cycling stream of actual movements that can be continually adjusted, e.g., by a person standing on shipboard during a rolling sea or by bicyclists. Oscillatory balancing signals are like those shown for wagging but with more developed capacities for variation.

Saccadic balancing uses one jump to balance another jump. Unlike the static and oscillatory forms, both of which incorporate continuity, saccadic balancing can be abrupt, opportunistic and creative. Please recall the discussion of the Hebrew word *regha*' in § 5.1. Revenge or "getting even," is a primal form of saccadic balancing. The *lex talionis*, "eye for eye, tooth for tooth" imposes symmetry on saccadic balancing to limit the violence and perhaps interrupt 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. Saccadic balancing is especially useful when jumps can be composed and compared or when movements can pivot between forms, possibly leading to shimmering balancing and/or to oscillatory balancing.

Some saccadic forms are based on repeated abrupt reversals of action, e.g., in soccer, where first one side charges in one direction on the 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 his calculated 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 a plaintiff money for pain and suffering, providing cash solace for an undeserved injury and loss of part of the plaintiff's actual life.

In the domain of brains, the ***vestibulo-ocular reflex*** or VOR observed in many animals is strongly suggestive of saccadic balancing. If you gaze at a fixed object and 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 when 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 (ocular) eye muscles. The size and direction of eye muscle jerks compensate or balance for the head jerks to maintain the gaze fixed on the object. A characteristic of invariance (the fixed gaze) is being maintained by balancing one kind of jump with another kind of jump. Such maintenance of invariance is a development of previous discussions involving Jaws for Cracking Nuts.

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. Imagery stands on that balanced foundation.

Constructions based on balancing forms make up the rest of the essay. Balancing forms are introduced in an experiential way through discussion of footraces and civil jury trials. The discussions are intended to ground constructions in actual life. A chief subject is symmetry and asymmetry in events controlled by balancing forms. Symmetry maintains balance and asymmetry leads to loss of balance.

The four kinds of activation thus lead to four kinds of control exemplified through balancing forms. Each kind of control uses a distinct kind 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 continuous processes, saccadic processes and shimmering processes are also generators of ***imagery***, which identifies, indexes and encodes a person's experience, including experiences of sights, sounds, bodily movements and positions. Such imagery may be recorded and reconstructed in ***memories***. My focus is on imagery that can be so remembered. Imagery and memories can influence selections that occur during saccadic and shimmering processes.

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

1. How do pulsating material bodies, whether in brains or in new device technologies, generate imagery that is a basis for selections?

2. How do selections based in imagery lead to muscular movements in animals and persons; or, alternatively, to action-producing pulsations in devices?

3. How do selections based in pulsations and imagery connect to a person's actual experience, e.g., to sights, bodily sensations and muscular movements of a baseball player deciding whether to swing the bat at a pitched ball?

I propose answers to these questions. My proposals are not wholly satisfactory. Obviously, they lack actual operating devices that might demonstrate certain phenomena — or fail to demonstrate such phenomena as the facts should prove.

In my view, problems of "consciousness" resemble problems that attended the development of electromagnetism in the era of Michael Faraday (1791-1867) and James Clerk Maxwell (1831-1879). Certain phenomena are known but there is no unifying approach. In the earlier era, inventions of electrical dynamos and motors (interconverting electrical, magnetic and mechanical energy) suggested potential developments but also revealed failures of understanding.

In § 6, I compare questions of imagery to those of electromagnetism, where there was originally no known connection between electrical currents and magnetic attractions and repulsions. Such connections were discovered and constructed through efforts of Ørsted, Faraday, Ampère and Maxwell. Faraday used imaginary ***fields*** to model both electrical currents and magnetic interactions. Maxwell saw that changing electrical fields generated changing magnetic fields, that changing magnetic fields generated changing electrical fields and: 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 imagery is like magnetic attraction and repulsion?

Development leads to construction of sub-classes of experiences, imagery and memories, beginning with those anchored to a person's body and extending upward in terms of organization and control. Sub-classes include: pain, sound, touch, hunger and thirst, muscular movements, bodily positions, smells, tastes, sights, sounds, words, desires, goals, deeds, events and courses of action.

I suggest that imagery generated by continuous activation includes temperature, pressure, pain and continuous sounds. Imagery of sensation and movement is generated by saccadic activation. I suggest that such imagery alerts an animal and enables it to orient to sources of changes and to initiate action. Action may be initiated for the sake of initiating action and selections may have only a crude relationship to environmental changes, e.g., limited to fighting or fleeing.

Persons also use imagery generated by shimmering activation to make more detailed selections on the basis of forms, e.g., "stop on red, go on green." Such selections require a higher level of "awareness" than simply being alerted, oriented 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 driver may enlarge the range of his awareness by blowing a horn.

Waiting at the traffic light, the motorist monitors the signal and continues to stop, until he goes. The situation is so simple that we say "the changing traffic light caused him to step on the accelerator" when, from a broader point of view, it is his habit or his destination that is the causal agent, if anything is. Maybe he is on his way to his job and if it weren't for the kids, he would have stayed in bed. Or, perhaps, he is repeating his weekday routine for its own sake.

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 dinner menu. In such situations, the first attempt to fit to form may be repetition or reconstruction of a past memory. Such a repetition may succeed in the present situation. If not, maybe imagery can be modified by changing pieces according to other memories. We notice discrepancies between a present situation and past situations; such discrepancies lead to additional modifications or to changed decision.

Taking another example, I suggest that, under the influence of imagery generated by memories and mental operations, the awareness of a person preparing to make a move in a chess game may "jump" from one possible move to other possible move – and back and forth in a reversible fashion – before "settling on" an actual move. A selection of a move may be determined by comparing possible compositions of moves to one another or by comparing such possible compositions to conceptual forms stated in chess books, such as recommendations for pawn structures. Different kinds of selection can be combined when making an actual selection.

I suggest that a person's imagery is generated in diverse layers and with patches of different kinds. Imagery is not of a single kind nor is it based on a single set of principles. Depending on situations, imagery is subject to organization, to different and conflicting organizations and to re-organization. Images are blended under some circumstances and distinguished under other circumstances.

Anticipated designs of device models for imagery start with musical tones and harmonies as the simplest continuous case. Signals in tuned and resonating devices go through repetitive phase changes that are the suggested origins of imagery. Similar models are used for pressure and pain that locate sensation on maps of the body that are laid out in a brain. Hunger and thirst are projected onto appropriate places in such maps. Development leads to saccadic moments of imagery flickering 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 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. Our imagery further develops through shimmering activation that operates by means of forms, such as forms of family, language, sports, music, mathematics, technology and institutions. Such forms control personal lives and the character of a community. History shows the powers of spiritual imagery and spiritually-inspired forms as high-level controllers.

In sum, a flickering foundation of body-based 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 influences, to forms and to detailed memories. In a larger perspective, all the imagery depends on the collective activities of human beings working together in a civilization. The species depends on a world-wide 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.   United 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 can influence actual life.

Shimmering Sensitivity arises at critical moments in shimmering processes. Shimmering Sensitivity can be sustained, in a flickering fashion, through repetitive cycles of critical moments that carry content from one critical moment to the next, like a circus performer walking on a high wire. In normal walking, every step includes a fall, usually stopped by a small collision with the ground. With every step on the high wire, the circus performer falls, begins to lose her balance and then catches it again. Shimmering Sensitivity is activee during a fall.

The principle of Shimmering Sensitivity is based on physicists' 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 magnets. Such a collection is ***disparate***; as a class, the materials have little in common besides critical point transformations. Critical point transformations belong to the more general class of phase transformation that also includes pearlite/martensite and snowflakes; and critical point transformations present features in common with them such as discontinuity and complete change of form. In addition, critical point transformations have special features. A critical point transformation occurs only at a specific temperature; e.g., the critical temperature or Curie Temperature for iron magnets is at 770 °C. Notwithstanding different critical temperatures and disparate kinds of materials, critical point transformations have important features in common. Away from the specific critical point, activities of disparate materials may have essentially nothing in common. The widely disparate critical point systems and their networked relations involving critical point transformations establish a principle of ***universality***.

The principle of universality is important in my constructions because it suggests that various device modules with differing designs can go through shared critical moments. I suggest that such universality is reflected in the nature of experiential imagery that has multiple forms co-existing in a person's "mind," e.g., in mixed forms like metaphors and analogies. Resonating principles of device design 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 having different forms but sharing a single critical moment add up to integrated experiential imagery that can be indexed, stored and reconstructed though processes of memory.

Viewing other aspects, water, as steam, resembles an Ideal Gas at one extreme of conditions and passes through a critical point at another extreme. A process that carries water from the critical point to Ideal Gas conditions resembles the passage of a device system that moves from delicate selections controlled by shimmering activation to sudden, strong muscular movements controlled by saccadic activation, such as a device system suggested above that models an "act of free will."

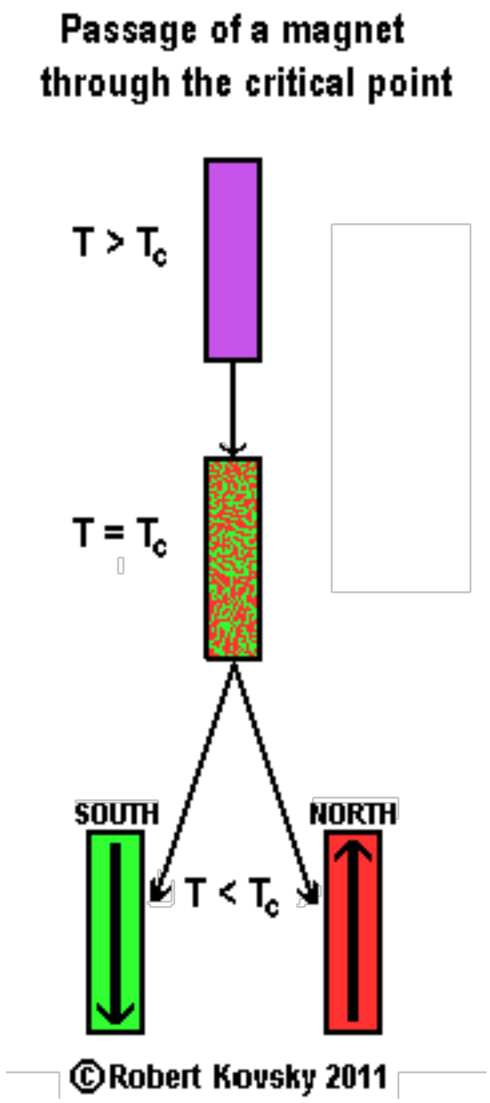
Critical point systems and Ideal gases each have a successful mathematical model that applies to a broad class of actual material systems. Critical point activity has been described by the mathematical ***Ising Mode***. Lars Onsager, the previously-discussed winner of a Nobel Prize for his reciprocity relations, provided a closed-form mathematical solution for the Ising Model that led to "revolutionary" breakthroughs. (Domb.) The Ising Model is a quasi-static quadratic form that was a starting point for design of the activated Quad Net Model of brains.

As chief contrasting features, the Ideal Gas is fixed and conservational in its behavior but critical point systems are transformational and incorporate changes.

Within a system at the critical point, changes are always ongoing. The system never relaxes, in contrast to equilibrium systems that are always relaxed or relaxing.

As shown in online demonstrations of the Ising Model, phasic aggregates of material are continually coalescing and dissolving. There is rough ongoing balancing between coalescence and dissolution. In some systems, coalescence takes on multiple distinct forms. When such a multi-form system falls through the critical point, coalescence takes on one actual form.

The adjacent Figure shows the passage of a magnet through the critical point. The critical point is also known as the critical temperature, T_c or the Curie point. During such a process, the temperature T of the magnet undergoes a controlled change.



A magnet with a temperature above the critical point ($T > T_c$) has no intrinsic polarity. It will not orient with respect to an another magnet. When the temperature of such a magnet falls below the critical point ($T < T_c$), however, it acquires a north polarity or a south polarity.

At the critical point ($T = T_c$), both polarities co-exist within the magnet in transient aggregates that are continuously coalescing and dissolving.

Symmetries show that it is equally likely for a 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.

Close to the critical point ($T = T_c$), it is very easy to shift the magnet's polarity back and forth from south to north and back again. The magnet is very weak. When the T of the magnet falls to a certain amount below T_c, the polarity becomes fixed and the magnet becomes strong.

The foregoing critical point principles have been applied commercially in magneto-optical memory systems.

An important special feature of critical point systems is that every point within a system at the critical point affects every other point equally regardless of the distance between the points. This is because activity is so highly activated and so congested that activity quickly becomes ***nonlocal*** and a fluctuation at one point connects with fluctuations at distant points to sweep over the entire interconnected region in a shimmering way. I suggest that nonlocal critical point activity may be a basis for the ***binding principle*** that is puzzling to brain scientists.

A brain is made up of a great number of smaller compact bodies that are themselves made of neurons, which are the active brain cells, e,g,, compact bodies of neurons called nuclei and ganglia. Such compact bodies are more generally called ***neuronal groups***. (Edelman.)

There are thousands of neuronal groups in a human brain and they are interconnected through nerve tracts that are like bundled cables of wires. Some neuronal groups receive signals from sensory organs and some neuronal groups send motor signals to muscles. A large functional unit inside a brain, such as a thalamus, can be viewed as a clustered and layered structure of interconnected neuronal groups. Controllers of operations in the cerebral regions of the brain form groups of groups. Neuronal groups apparently work together, bound together by synchronized neuronal discharges. Scientists declare that there must be a principle behind such bindings. (Koch, Edelman & Tonini.)

Activities of neuronal groups are studied using advanced techniques of imaging, e.g., functional magnetic resonance imaging or fMRI that monitors the distribution of sugar carried by blood and consumed by active neurons. 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. Such a set of neuronal groups that are highly activated with respect to a specific task is called a ***coalition*** of neuronal groups. It is observed that neuronal groups synchronized and participating together in a coalition are widely separated in space within the brain. The spatial separation of synchronized groups working together is part of the binding problem.

I suggest that Quad Nets and Shimmering Sensitivity offer a solution to the binding problem. The solution is in the form of a proposed device process stated in words here and in device designs in §6.

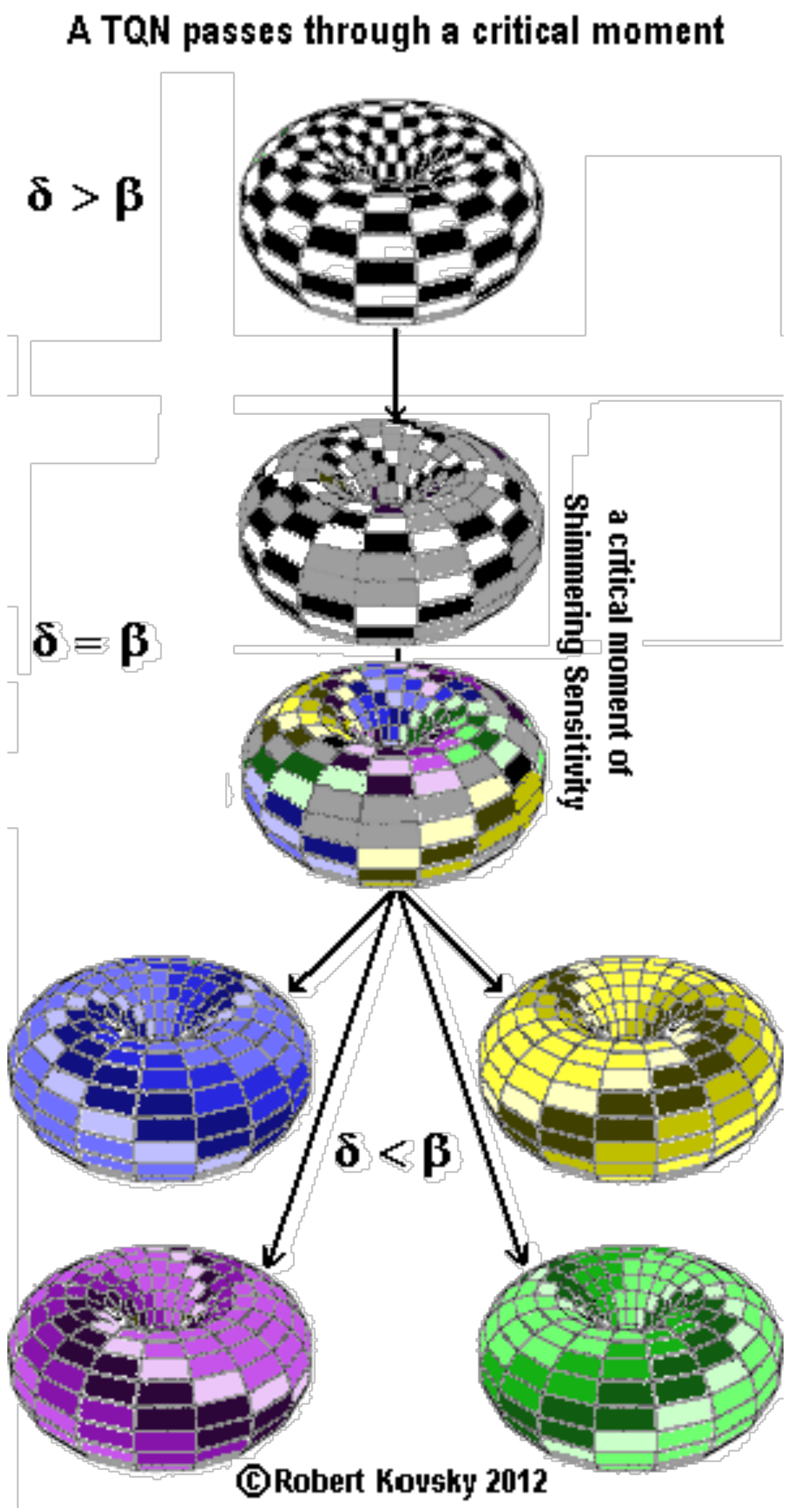
The process occurs in a device called a Toroidal Quad Net or TQN. A TQN is a collective device that models a neuronal group. Certain controlled operations of a TQN are shown in the Figure below. The collective device is made up of a square pattern of interconnected individual devices. Each individual device discharges pulses and a pulse discharged by one device triggers those of its neighbors that are ready. Please see the *Quad Nets* paper for full details and imagery. The TQN is shown in the Figure as if it were isolated. In operations, the TQN is connected to other devices that deliver pulses to it during critical moments.

Activity of the TQN is partially controlled by ***timing intervals*** δ and β. The responding period δ equals the time between the triggering of a device and its discharge of a pulse. The refractory period β equals the time between discharge by a device and its return to a ready condition, when it can be triggered again.

When δ > β, a discharging device that triggers a neighbor will return to readiness before the neighbor discharges. The result is "checkerboarding" or alternating discharges.

When δ < β, a device is still refractory at the discharge of a neighbor it triggered. The only steady pattern is a wave that moves in one of four directions. As with other sets of ticking clocks, ***entrainment*** unites devices into one steady pattern.

Critical point processes in TQN's resemble those seen in magnets. A shifting relationship between δ and β leads to a critical moment when δ = β.



During the critical moment, relatively weak signals from other devices generate multiple germinal wave patterns in the TQN and select the final wave pattern, which then becomes fixed for the productive part of the cycle.

In other words, passage of a TQN through the critical point generates a critical moment of Shimmering Sensitivity when $\delta=\beta$. At the commencement of the critical moment, activity in the TQN takes the form of germinal "wavelets" moving in all directions. As in magnets at the critical point, aggregates of wave activity coalesce and dissolve according to external influences. During such coalescence and dissolution, the device may be shimmering, jumping from pattern to pattern.

As the cycle continues, and as a result of unbalanced signals from other device parts, wavelets in one direction unite and take over the TQN, establishing simple waving activity. At the outset, any of the patterns is equally possible and the selection is highly sensitive to external influences. All kinds of competing influences can affect the selection and lead to one or another final pattern.

TQN's and other device parts can be organized in systems that maintain ongoing coalescence and dissolution of wave patterns. Advanced layered device parts can even generate circulating coalescence and dissolution that continues indefinitely.

I suggest that when activities of interconnected TQN's and other device parts are synchronized, they pass through critical moments together. Local activity within one TQN generates nonlocal activity in other interconnected TQN's and vice versa. Multiple channels of signals in interconnected devices can disorganize each other during critical moments and become re-organized as they emerge from transformation. Interconnected devices can generate a condition of shimmering in which resonating aggregates of activities in devices coalesce and dissolve. Shimmering can extend over an entire synchronized coalition: then, as the critical moment passes, selections occur in different TQN's and devices.

An influence that reaches the coalition through one TQN may affect selections in all TQN's. One set of patterns may be steady while other patterns go through changes that are subject to the steady patterns. A temporary or permanent hegemonic pattern may appear. 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. Such critical moments may be generated repeatedly and continually through cyclical activity.

I suggest that critical point properties show how multiple possible bodily movements can change into a single actual movement, similar to the way a cloud of water vapor changes into distinct crystalline snowflakes. I suggest that bodily changes can be modeled by phase changes in pulse patterns in TQNs.

I further suggest that critical point principles show how individualized experiential imagery and memories – e.g., a person's imagery and memories of movements, tactile sensations, limb positions, sights, sounds and forms – might be generated during phase changes in pulse patterns in neuronal groups in brains and have consequential power. The leap from phase changes in pulse patterns to experiential imagery is obviously speculation; but it seems clear to me that ***something*** is generating such imagery in my brain; phase changes and pulse patterns offer possibilities for investigation and development.

I suggest that such imagery, generated and sustained by synchronized and resonating coalitions of spatially-spread-out, interacting neuronal groups in a brain and fortified by memories, 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 or memories or set of forms can be invariant, controlling or hegemonic while other images or forms are modified to conform thereto. It would appear that selections of controlling forms can be made subject to overall control, that is to control maintained by the self and sustained by a bodily and social environment. The controlling and maintained forms make up a personality. The person maintains the controlling forms 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 that are mandated by society (stop-on-red/go-on-green) and to follow those forms when changing possible bodily movements into actual movements. (Didn't Plato say something similar?)

The principles are applied to solve free-will puzzles. Discussion in § 6.c shows how generation of imagery fits in with exercises of freedom and how quasi-static and isolated events of free-will puzzles are malformed for such an exercise. The chief counter-example is a baseball player at batting practice, training his skills by means of a pitching machine that throws ball after ball. Repetitious practice using memory sharpens performance and advances towards goals of success that are absent in unmotivated performances of free-will puzzles.

Methods of construction herein are different from methodology of platonic science. My constructions are specific and suggestive in contrast to claims of authority or rigor that further hegemonic goals of platonism. Proposed device designs offer exactitude and integrity based on construction principles, not on some supposed relationship between constructs and "reality." Instead of trying to explain a supposedly verifiable reality, there is an aim of connecting to actual life.

The chief focus is on temporal forms of ***balancing***. Balancing activity is grounded in symmetry; more precisely, such activity establishes and maintains symmetry and, while successful, ***maintains a balance*** that can be stated in terms of symmetry. Chief temporal forms of balancing also include a ***loss of balance***, which is a termination of symmetry that also terminates the activity of balancing. In constructing Shimmering Sensitivity, loss of balance becomes 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 only one direction. Once balance is actually lost, it can be immediately restored with minimal costs, under some circumstances, making continuous operations possible. Meanwhile, the actual loss of balance can be converted into selective muscular movements.

An idealized temporal form of balancing has a time prior to its existence, a point in time of its establishment, a period of existence and a point in time of its termination. Such temporal forms in general (including forms of balancing) are called ***episodes***. 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 separate identities and different times of birth and death. Episodes do not fit easily into invariant, symmetric forms that disregard individual differences and that try to treat all individuals or all episodes "the same."

The individual episode form is, however, sometimes suitable for the important purpose of incorporation into a ***tiling*** temporal form, which can approximate invariance. Tiling forms are repetitive and cyclical and they also hook up end-to-end to generate ongoing activity that can be self-perpetuating. Tiling forms often control other forms of activity. Some tiling forms, like an anniversary, are simple. In complex tilings, e.g., tournaments, a general form of activity is repeated cyclically but specific details vary.

Very often in actual life, muscular movements are practiced in the form of a tiling and then practiced movements are expressed in the form of an episode. For example, a baseball player attends batting practice where he swings at ball after ball thrown by a pitching machine. The pitching is in the form of a tiling.

The purpose of batting practice is to enable the batter to perform more successfully when the form of activity is episodic, namely, in the batter's box during an actual game. In actual life, it appears that successful practice in such tiled activity leads to greater success in episodic activity. Such practice is called "training." Facts suggest that, during training, visual imaging and memory functions are being smoothly coordinated with muscular movements and that such smooth coordination is carried over to episodic performance.

During each cycle in the batting practice example, a critical moment of decision for the player occurs when he either begins swinging the bat at the pitched ball or chooses to stand without swinging as the ball whizzes past. Prior to that extremely short critical moment, both possibilities are maintained in a balance that is symmetrized as equal for purposes of effective decision. The batter is equally ready to swing or to stand still. After that extremely short moment, the situation is perfectly asymmetrical: either the batter swung or he did not swing. Constructions herein focus on the generation and resolution of such critical moments.

To connect to actual life, I focus on ***strife***, especially strife occurring in sports contests and civil trials in court. The view starts with some general observations.

In many episodes of strife, animals compete for possession of a prize that may range from a carcass to a battleground highpoint to an Olympic medal to a court judgment. Each animal seeks both to gain the prize and to prevent competing animals from gaining the prize. Animals anticipate each other's actions with respect to the prize and act to frustrate others' attempts to gain the prize. The Greek word for prize is *athlon* — hence our "athletics."

Temporal forms of balancing are used in sports contests and civil trials. Such forms of balancing incorporate principles of symmetry and invariance that actually control and resolve strife. In actual life, I suggest, it is not music that quiets the savage beast, but prizes gained through controlled strife, using principles of symmetry and invariance, e.g., through embodiment in 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.)

Platonism is supposed to quell strife and remove all causes for strife. Platonism assumes the existence of a single-minded and cosmological set of principles that can be declared by an institution of specialized 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 his glorification of strife. E.g.: "*Out of life's school of war*: What does not destroy me, makes me stronger." (*Twilight of the Idols*, Maxim 8.)

Ancient texts also glorified strife. Major topics 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. 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.

There are various modern approaches to strife. 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 famous 20th century military strategist, Capt. B. H. Liddell-Hart, worked principles of war into metaphysical principles in *Strategy: The Indirect Approach* (1954), 347-350. Every county government in the United States, or nearly so, has a 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 satisfactory solutions.

Given inherent difficulties of the topic of strife and many diverse approaches, my approach is to narrow the focus of attention and to try to grasp something essential. Our need for new ways to deal with strife identifies important long-range goals of development of principles directed at the character of institutions and design of more effective institutions. Constructions herein revolve around principles of balancing. We use balancing principles in various ways, including resolution of strife within the governance of institutions.

The 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 6 minutes.

Strife in a footrace is constrained by formal features that incorporate principles of symmetry and invariance. The geometry of the track is designed to give every contestant an equal opportunity. Individual lanes of travel present a functional symmetry such that a contestant should be indifferent as to lane assignment. All contestants get the same signal to start. Contestants stand as equals before neutral officials and neutral rules. Rules are the same for all races of a specific kind regardless of where or when the race is run.

During the race, each contestant engages in action that has a similar course. The race starts at one line and according to one signal that are common for all runners and finishes at another 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 all these features, comparison of contestants' speed can be made directly, according to the order they cross the finish line. The first to cross the finish line "wins" the race and winning is the purpose of each runner. Only one runner can win and runners compete to exclude each other from winning. Each runner seeks to inflict defeat on each of the other runners. The conflicting purposes of the runners are the basis of strife in a footrace.

The foregoing symmetrical and invariant features provide a system of constraints for a footrace, a ***form*** for a footrace. The existence of the footrace depends on such formal features and the character of a race, e.g., as a "fair race," is based on the occurrence of such formal features during the actual event. It is such formal features that make a footrace suitable for institutions like colleges that hold sports competitions. The track incorporates spatial forms of geometry that share in the universal acceptance of geometry. 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, runners accept the outcome and return for more races of the same kind. Institutions, like babies and runners, do things for the sake of doing them. Following the forms is a function of the life of the institution.

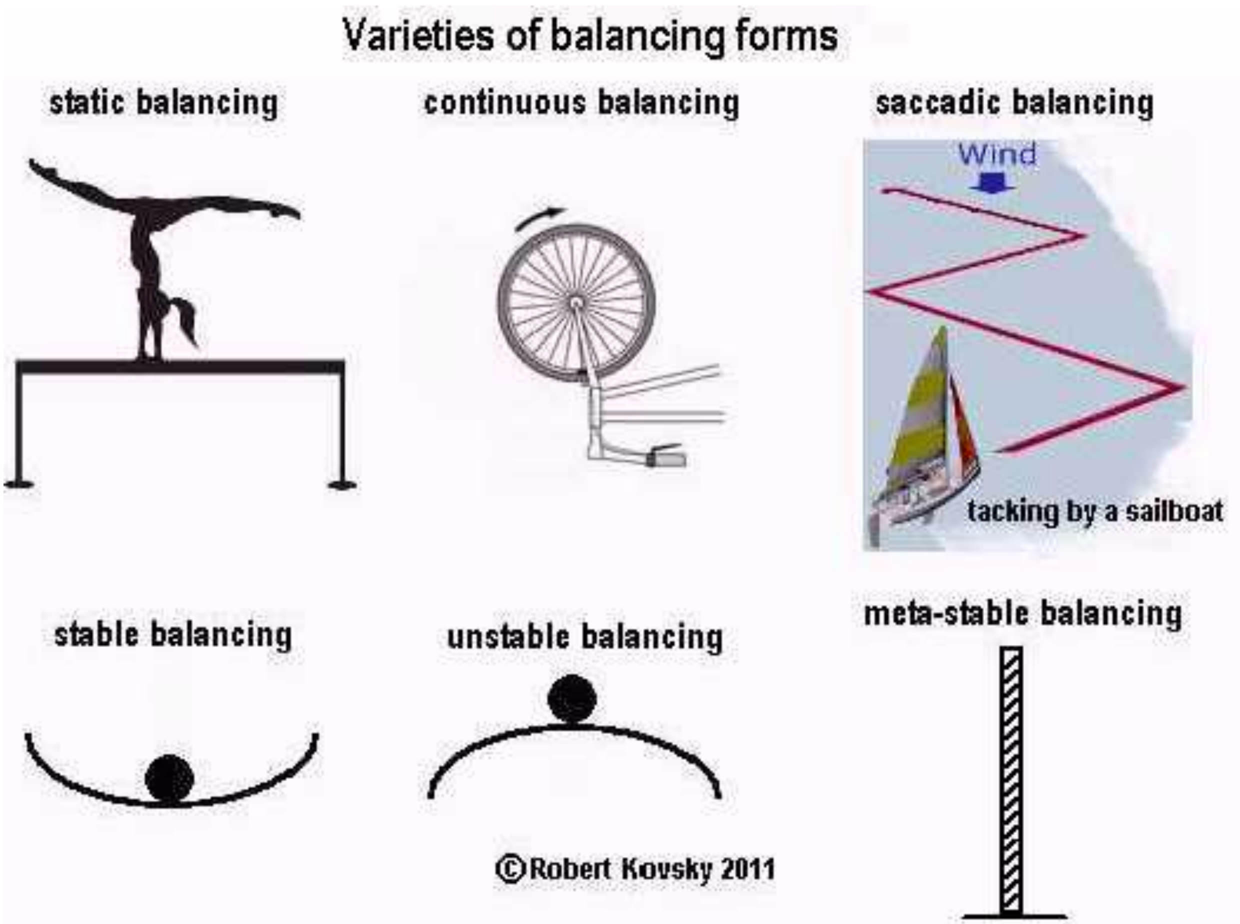
The symmetrical track and invariant, symmetrical rules only provide a container for the actual running of a footrace. In an earlier work available on my website, *The Crucible* (1992), I compared institutional activity of a court to activity of a metallurgist inventing a new alloy. The metallurgist uses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

The actual running of a footrace is controlled by temporal forms. To highlight and dramatize balancing forms, we consider a race with only two contestants, "he" and "she." At ordinary moments, exactly one contestant is in the lead. There are also special moments of overtaking or challenge when no one is in the lead. A moment is a compact period of time that may be short or extended. From start to finish, the race is one extended moment that fits the episode form.

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 the other runner. Such moments are like phase changes in materials, e.g., when water changes into ice. During such moments of passing, the activity changes in a fundamental way.

The three temporal forms “overtaking,” “leads all the way” and “see-saw” make up a complete set for forms, even though they may not be entirely satisfactory, e.g., in the indefiniteness of the see-saw form. “Complete” means that any actual two-person race can be said to fit one of the forms. It is possible to conceive of a race where the fit is poor, e.g., “neck-and-neck,” but such a race is special and a few anomalies do not defeat the completeness principle, at least not in my approach. A set of forms is a useful tool for organizing activities and a complete set often has more uses, regardless of anomalies. Small children learn to distinguish and fit spatial forms like circle, triangle, square, star. Similar skills can be applied to temporal forms, e.g., musical forms waltz, march, triplets, ballad. Musical keys make up a complete set of temporal forms, at least for popular kinds of music.

Balancing forms combine a spatial aspect with a temporal aspect. The spatial aspect is a symmetry between parts. The temporal aspect is the form of activity that maintains the symmetry and that controls any loss of symmetry. As shown in the Figure below, some temporal forms of balancing can be represented by a symbolic form and given a name or verbal form. Such forms of balancing are named static, continuous, saccadic, stable, unstable and metastable.



An additional temporal form of balancing can occur during a footrace, a form called "closing the gap." Closing-the gap-balancing occurs in an episodic way around moments of challenge and/or passing.

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 is running faster 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 speed. If he maintains his speed and she maintains her 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 pass 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.

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. 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, pass him and win the race.

As modeled by An Eye for Sharp Contrast, the gap is measured by muscles that control the focus of the Lens of the Eye. Her visual image may be based on a visual edge presented by his body, but an edge offers little opportunity for "extracting" a distance. There is, rather, a direct relationship, something like a linear relationship, between signals to eye muscles and distance to the object. I suggest that the extra muscular effort of the legs that is needed to close the gap is measured by muscles of the eye. The visual image is just something to focus on.

Please recall discussion of the VOR, showing that the foundation of a stable visual image is based on muscular movements of eyes that balance head movements.

Suppose that the extra effort she summons up 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 the region where 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 pass 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 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 is in the form of 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. It is a differential quantity of effort. Extra effort is identified, indexed and encoded by a visual gap between the leading runner and the challenger. Added speed from extra effort can balance or even over-balance a spatial lead.

The additional balancing form is characterized by 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.

Similar reasoning applies to trials in courtrooms. Legal proceedings share many features with sports competitions, chiefly resolution of strife by means of contests that lead to definite outcomes and that involve prizes. A trial has a critical moment of decision by the jury, namely, the time when the jury is deliberating in the jury room. All activity of a trial is aimed at influencing that critical moment.

Shifting from the focal critical moment to the encompassing 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 keep the peace; to protect personal rights, property possessions and transactional integrity; and to put an end to disputes involving individuals and/or private organizations.

A contrasting feature of the two domains is that legal contests have consequences that are weightier than those of sports contests, often involving accusations of dishonesty or with financial stakes of serious importance to the parties. Stakes in criminal proceedings include imprisonment or death of the defendant.

A "court" is a place where a judge presides; often the judge is called "the court." In the courtroom, 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. Usually, action by the sheriff is not necessary and the evicted tenant will move out before the sheriff arrives. The territorial area in which the sheriff or other peace officers will perform such acts of enforcement according to the judge's orders defines the court's ***jurisdiction***.

Both sports and courts employ symmetrical and invariant forms of contest to control and resolve strife. 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, an 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; ongoing 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 of states, 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 all such metaphysical domains. Constructions put together in such metaphysical domain are supposed to control actual lives.

It is undeniable that judges, do control actual lives through powers of the state. If the court enters a money judgment in favor of plaintiff and against defendant, the sheriff will instruct bank officers to transfer money from defendant's bank account to plaintiff's bank account and bank officers will comply with such instructions..

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. There are widespread beliefs that simple mechanical connections exist as part of the inherent nature of things. (Frank, *Law and the Modern Mind* (1930, 2d. ed. 1935), "The Basic Myth.") Another view is that claims about such connections are fabrications that camouflage the hegemony of a ruling class. According to this view, it is asymmetrical injustice that is invariant. A third view is that court decisions are arbitrary, lacking symmetry or invariance despite illusions or pretenses to the contrary; rather, they are based on political positions of judicial appointees or unconscious prejudices of jurors. Supposedly, the decider aims for a particular outcome and writes or says whatever appears to fit or suit that aim. Such views are topics of academic discourse.

My own views are rather different. Yes, many cases support each of the stated views. However, what actually happens often has a more practical character.

I begin with actual decisions made by judges and jurors and trace them back to shaping influences. Such decisions have specific terms. Such specificity is required to perform certain tasks, e.g., an order or judgment must be enforceable without need of interpretation by staff working in the sheriff's office. Such an order or judgment must be so clear and unambiguous that no questions arise. Any metaphysical principles should be efficiently directed towards production of such a specific order or judgment.

I suggest that certain ***legal forms*** provide 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 court proceedings, judges and jurors use legal forms to make decisions and reach specific results. 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. For example, some terms in legal forms are highly specific and other terms are quite vague. As discussed below, such vague or ***ambiguous*** terms in legal forms authorize judges and juries to exercise freedom in turning metaphysical principles into specific forms of orders and judgments.

Thus, 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, judge and jurors make decisions where they are sensitive to multiple influences. At the later stage of proceedings, the sheriff carries out orders that should be entirely unambiguous. This course of action resembles the courts of action suggested for devices in an earlier discussion of "free will."

Judges and jurors also follow forms that call on them to be personally indifferent to the outcome and to be insulated from unauthorized influences. Judges and juries follow all such forms because following forms is the essence of all institutional activity, with roots in religious and community rituals. Institutions operate through forms and institutions discipline persons who fail to follow forms. Persons involved with institutions follow forms for the sake of doing so and are engaged in self-perpetuating behavior that is called "duty" in an institutional context.

Legal forms of many different kinds are published by specialty business firms that have venerable names. Published sets of legal forms have huge sizes and law libraries have racks of them. Learning use of legal forms is part of a law school course on legal research. Attorneys have duties of lifelong education about changes in legal forms.

A chief legal form used during critical moments in trials is the ***jury instruction***. After presentation of evidence and argument in a trial, 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 and a set of possible verdict forms – 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. Sometimes jury instructions are printed in a booklet that jurors take with them.

Jury instructions are, in my view, pivotal forms in trial proceedings. They are actual means for turning evidence and argument into judgments. 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.

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 and as a means of punishing Simpson. 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 answered questions:

"Question No. 1: Do you find by a preponderance of the evidence that defendant Simpson wilfully and wrongfully caused the death of Ronald Goldman? Yes. … Question No. 8: We award damages against defendant Simpson and in favor of plaintiffs: … $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. Techniques include presentation of opposing authoritative pronouncements from hired "scientific experts." It may happen that neither side's evidence is credible and that the decision is actually made for other reasons. Fitting the form may be crude, clumsy and forced. Imperfect fits are common in civil litigation. Such crudeness and clumsiness allows many cases to fit a form, even if imperfectly.

Attempts to balance disparate matters do not fit the nature of a mathematical calculus, which deals with 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. Various kinds of influences have to be accommodated. Put into practice, such rules allow a manufacturer to sell a product that has dangerous uses 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 users short of withdrawing the product from the market or making it prohibitively complicated or expensive. To support such a defense, large bright red warning labels are advisable.

Balancing tests are generalized when the jury is called upon to ***weigh*** 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.

Important features of balancing forms are shown by reference to device models.

Balancing forms used in footraces can be modeled using continuous activation; models of balancing forms used in civil trials require saccadic and shimmering activation. The gap in a footrace, a spatial quantity, becomes a formal ***distinction*** (or a structure of distinctions) in a civil trial. 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 distinction, in contrast, states a difference in kind that identifies, indexes and encodes the need 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. Temporal forms of balancing that are chiefly muscular in a footrace have counterparts in legal forms that are chiefly conceptual.

The gap in a footrace defines a pivotal space that separates two runners in an athletic domain; a distinction in a courtroom defines a pivotal fact that separates two cases in a judicial domain. Such a space and such a fact may have similar decisive importance in corresponding critical moments that decide outcomes.

The character of distinctions in legal forms is illustrated by the historical development of legal rules for treatment of workers injured during the course of employment. Such injuries are frequent. Changing social and political attitudes have led to changing rules for employers to provide treatment 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. Apparently, slavery was rare in ancient Babylonia and employment was mostly contractual. Subsequent civilizations were based on slavery, feudalism, indenture and paternalism; whatever their defects, such employment relationships established a basis for employer responsibility for care of injured workers. The Industrial Revolution changed employment relations. (Herlick, § 1.01.) It also led to enormous increases in injuries to workers.

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. 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 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 previous constructions, I suggest that balancing forms are used throughout legal proceedings, even appearing in symbols of justice and of the legal profession. Legal balancing forms have common roots in actual life with balancing forms of sports competitions. All such forms are grounded in symmetry and invariance and in all such forms, changing asymmetries are of central importance. Balancing forms combine spatial forms and temporal forms.

The construction concludes with development of previously-discussed principles into a view of jurisprudential law and metaphysical constructions based thereon. Jurisprudential law is stated in law books, including written statements of law in constitutions, statutes and court decisions. Jurisprudential law states fixed principles that are supposed to control legal proceedings in courtrooms. Of even greater consequence, jurisprudential law states fixed principles that are supposed to control actual lives of persons in society. However, as Oliver Wendell Holmes, Jr. famously wrote about that question, "General proposition do not decide concrete cases." Lochner v. New York, 198 U.S. 45, 76 (1905)

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. Frank stated something similar in *Law and the Modern Mind*, discussed below. Scientific law applies "shalt" and "shalt not" to material bodies. In jurisprudential law, the body is called a person. E.g., a material body that is dropped from a height must fall; and a person must not drive a motor vehicle through a red traffic light.

In other words, the primal form of a law is a mandatory or prohibitory statement applicable to a class of activities of a class of bodies. Pursuant to the form, the law must apply to all 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 actual results do not fit the primal form and where the primal form cannot be usefully applied. As a matter of fact, a traffic cop has freedom not to issue a ticket to a personal family member who drives through the red light. In another case, a motorist may argue that the light was yellow when she entered the intersection. A primal form of law also fails to apply in some scientific situations, e.g., as to snowflakes where a multitude of symmetric shapes is possible and laws fail to explain the phenomena. Another example is the photoelectric effect that could not be explained in terms of laws based on Electromagnetic Waves. When the primal form of law fails in scientific situations, scientists often try to use models based on probabilities; but probabilistic results are less satisfactory than lawful results. When the primal form fails to resolve a legal dispute, legal forms authorize judges and jurors to exercise freedom.

Investigation into jurisprudential law starts with three basic theories 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) discussing principles of 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 instruments 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 are risky vehicles for precious metals or money. It is much safer and easier to take a piece of paper that entitles the identified bearer to get or deposit money, so long as counterparts in such transactions are reliable. In medieval times, especially in ports around the Mediterranean Sea and the 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 uniform forms led to legislative enactment of codes of laws regulating Sales. Various 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.) Customs turned into strict and novel standards, e.g., those stated in printed warranties that come with 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 what it suits its practical 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. 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. There is a social or commercial interest in having uniformity of rules and that social interest should influence decisions. A social interests approach looks to goals for the future rather than to supposed origins of law.

The social interests approach developed during the late 19^{th} and early 20^{th} centuries. It is identified with Oliver Wendell Holmes, Jr. (1841-1935). Holmes fought and was wounded in the American Civil War, wrote major Supreme Court opinions and welcomed newly-elected President Franklin D. Roosevelt to Washington in 1933. He famously announced the advent of the new era: "The life of the law has not been logic; it has been experience." (*The Common Law* (1881) at 1.)

In *The Path of the Law* (1897), Holmes wrote:

> "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***." (Emphasis added.)

From my perspective, Holmes was declaring an ***actual jurisprudence*** that takes as its chief subject matter the actual decisions, practices and procedures of courts and other institutional deciders. When social interests jurisprudence was achieving prominence in the 1930's, it was called ***Legal Realism***. A leading legal realist was Jerome Frank (1889-1957), who 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 labels for them like "legal fundamentalism" and "mechanical jurisprudence." Please compare to "platonic science" herein.

The focus of actual jurisprudence is on exercises of freedom by judges and juries. Laws are stated in traditional formulations of mandates or prohibitions that apparently apply to classes in invariant and symmetrical ways. Such formulations are not suitable for the personalized decisions that actual disputes require. In order to accommodate and allow for such personalized decisions, judges and legislators introduced ***methods of ambiguity***. An ambiguous term must be interpreted and an interpretation of ambiguity can take into account all sorts of considerations that can lead to all sorts of results. Using methods of ambiguity, judges can exercise freedom in deciding disputes.

Such freedom was described by Gilmore & Black in *The Law of Admiralty* (2d ed. 1975), § 10-20 in connection with a particular issue. Some background provides context. United States Congresses enacted and Presidents signed bills that, in the aggregate, are called the Limitation Act. Included in the 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 cargo. 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***.

6. In contrast to computers that use static forms and embody spatial principles of platonic science, timing devices and Quad Nets are new technologies that use temporal forms and embody principles of action and freedom.

[To be completed]

References

T. Boman, Hebrew Thought Compared with Greek (1960).

D. J. Boorstin, The Mysterious Science of the Law: an Essay on Blackstone's Commentaries (1941, 1996)

P. W. Bridgman, The Nature of Physical Theory (1936).

S. Claesson, Award Ceremony Speech for the 1968 Nobel Prize in Chemistry to Lars Onsager, http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1968/press.html

J. M. Cooper, M. Adrian, R. B. Glassow, Kinesiology (1982).

C. H. Dodd, The Interpretation of the Fourth Gospel (1953).

C. Domb, The Critical Point: A historical introduction to the modern theory of critical phenomena (1996).

G. M. Edelman, Neural Darwinism: The Theory of Neuronal Group Selection (1987).

G. M. Edelman & G. Tononi, A Universe of Consciousness: How Matter Becomes Imagination (2000).

A. Einstein, "On the Electrodynamics of Moving Bodies," (1905) in The Principle of Relativity (collected papers, Dover).

A. Einstein, The Foundation of the General Theory of Relativity (1916) in The Principle of Relativity (collected papers, Dover).

P. Feyerabend, Against Method (3d ed. 1993).

L. M. Friedman, A History of American Law (1973).

R. P. Feynman, The Character of Physical Law (1965).

R. P. Feynman, Feynman Lectures on Physics, Vol. I (1963).

J. Frank, Law and the Modern Mind (1930, 2d. ed. 1935).

L. L. Fuller, Anatomy of the Law (1968)

J. W. Gibbs, Elementary Principles in Statistical Mechanics (1902).

G. Gilmore, The Ages of American Law (1974).

G. Gilmore & C. L. Black, The Law of Admiralty (2d ed. 1975).

H. Goldstein, Classical Mechanics (1968).

H. L. A. Hart, The Concept of Law (1961)

S. Hawking, A Brief History of Time: From the Big Bang to Black Holes (1988).

S. D. Herlick (Raasp ed.), California Workers Compensation Law (2010 release).

O. W. Holmes, Jr., The Common Law (1881).

O. W. Holmes, Jr., The Path of the Law, 10 Harvard Law Review 457 (1897).

Judicial Council of California, Civil Jury Instructions (CACI, 2011 versions).

T. Kaplan, M. J. Aziz, L. J. Gray, Restricted applicability of Onsager's reciprocity relations to models of interface motion (1993) http://seas.harvard.edu/matsci/people/aziz/publications/mja063.pdf

W. Kaufmann, Discovering the Mind, Vol. I, Goethe, Kant and Hegel (1980).

W. Kaufmann, Discovering the Mind, Vol. II, Nietzsche, Heidegger and Buber (1980).

W. Kaufmann, Discovering the Mind, Vol. III., Freud versus Jung and Adler (1981).

C. Koch, The Quest for Consciousness: A Neurobiological Approach (2004).

R. Kovsky, "An Ear for Pythagorean Harmonics," (2009), http://www.quadnets.com/eph/eph.html

R. Kovsky, "An Eye for Sharp Contrast," (2010), http://www.quadnets.com/esc/esc.html

R. Kovsky, "Facts About Snowflakes," (2009), http://www.quadnets.com/testimony/snowflakes.html

R. Kovsky, "A Patchwork Of Limits: Physics Viewed From an Indirect Approach," (2000), http://www.quadnets.com/bodicom/ptchwork.html

R. Kovsky, "Quad Nets: Material Foundations for Thermal Device Models of Brains," (2006), http://www.quadnets.com/QNpaper.html

R. Kovsky, "The Crucible: Structural Foundations of Consciousness and Freedom," (1992), http://www.quadnets.com/bodicom/crucible.html

Lamb, Hydrodynamics (1879, Dover reprint, 1945).

K. G. Libbrecht, Designer Snowflakes, Part III, "Precision Snow," http://www.its.caltech.edu/~atomic/snowcrystals/designer3/designer3.htm

K. G. Libbrecht, "Frequently Asked Questions," http://www.its.caltech.edu/~atomic/snowcrystals/faqs/faqs.htm

B. H. Liddell-Hart, Strategy: The Indirect Approach (1954).

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

H. Minkowski, "Space and Time," (1908) in The Principle of Relativity (collected papers, Dover).

M. Minsky, Society of Mind (1985).

P. Morse, Thermal Physics (1964).

NASA, "Nakaya's Snowflake Classification System," http://mynasa.nasa.gov/pdf/183516main_nakaya.pdf

F. Nietzsche, Beyond Good and Evil (Kaufmann trans. 1966).

F. Nietzsche, Thus Spoke Zarathustra in The Portable Nietzsche, Kaufmann ed. (1961).

F. Nietzsche, Twilight of the Idols in The Portable Nietzsche, Kaufmann ed. (1961).

F. Nietzsche, Will to Power (Kaufmann trans. 1968).

P. Penfield, Jr. and H. A. Haus, Electrodynamics of Moving Media (1967).

R. Penrose, The Emperor's New Mind (1989).

J. Piaget, The Child's Conception of Space (1948).

J. Piaget, The Child's Conception of the World (1929).

J. Piaget, The Child's Construction of Reality (1937).

J. Piaget, Judgment and Reasoning in the Child (1924).

J. Piaget, The Origins of Intelligence in Children (1936).

J. Piaget, Structuralism (1968).

K. R. Popper, "The Nature of Philosophical Problems and their Roots in Science," (1952), in Conjectures and Refutations, the Growth of Scientific Knowledge (1963).

K. R. Popper, The Open Society and Its Enemies (1950).

I. Prigogine & I. Stengers, Order Out of Chaos (1984).

G. de Santillana, The Origins of Scientific Thought (1961).

A. Schweitzer, Paul and His Interpreters (1912).

L. Slattery, K. Butigan, K. Preston-Pile, Engage: Exploring Nonviolent Living (2005).

M. Sprackling, Thermal Physics (1991).

C. Taylor, Sources of the Self, The Making of the Modern Identity (1989).

R. C. Tolman, The Principles of Statistical Mechanics (1938).

C. Truesdell, Rational Thermodynamics, Springer (2d ed. 1983).

C. Truesdell & W. Noll, The Non-Linear Field Theories of Mechanics (3d. ed. Antman 2004).

C. Truesdell, The Tragicomedy of Classical Thermodynamics (Udine version 1971).

W. A. Wallace, Causality and Scientific Explanation (1972).

W. G. Walter, The Living Brain (1953).