# Hossein Jorjani

https://hosseinjorjani.com/

hosseinjorjani2@gmail.com

## On dialectic (2): Re-visiting dialectic

[This is part one of a three-part article series.]

[On dialectic (1): What is dialectic]

[On dialectic (3): Alternatives to dialectic]

**For the latest version and a PDF copy, please see the following link:**

https://hosseinjorjani.com/dialectic/

# Revision history

**2025-06-24**
**2025-07-12**
**2025-09-10**

# Contents

# 1. Abstract

This article offers a critical examination of the dialectical principle that quantitative accumulation leads to qualitative transformation — a core tenet of Hegelian dialectics — and evaluates its scientific validity. Using explicit methodological criteria (continuity vs. discontinuity, internal vs. external causation, novelty, predictive adequacy, and conceptual coherence), the article tests seven widely cited examples from physics, chemistry, and biology, including phase transitions, incandescence, magnetic polarity reversal, allotropy, the hydrocarbon series, the periodic table, and punctuated equilibrium. Each case is shown to be more accurately explained through continuous, externally mediated, or probabilistic processes rather than through internal contradiction or ontological leaps. The analysis reveals that the "quantity-to-quality" transition, often invoked as a universal law, lacks empirical substantiation and methodological coherence when subjected to modern scientific scrutiny. The article concludes that while dialectic may retain heuristic or rhetorical value, its extension into natural sciences (and, by analogy, social sciences) as a lawlike explanatory framework is unwarranted. More broadly, the attempt to legislate nature by contradiction risks collapsing into metaphor, obscuring rather than clarifying the causal diversity of natural processes.

# 2. Introduction

In the first article of this series (Jorjani, 2025), the history of the concept of dialectic was reviewed. It was shown that dialectic began as a relatively simple tool (*simplicus*), used for inquiry and conceptual clarification (e.g., in Socratic dialogue), and gradually acquired additional "building blocks" (further simplicus) until it became a complex system (*compositum*) embedded in broader philosophical frameworks [1].

Before Hegel, dialectic functioned mainly as a methodological instrument within epistemology and rhetoric — a way of engaging contradiction to test positions and clarify concepts (Rescher, 2006). With Hegel, however, dialectic was redefined as the immanent logic of thought and reality: contradiction became constitutive of motion itself, not merely a feature of discourse (Houlgate, 2005). This marked a

---

[1] *Simplicus* is a coined technical term (from *simplex, simplicis*), used here to denote a non-composite theoretical structure. *Compositum* is the classical Latin term for a compound or composite structure. For consistency with certain English and Latin nouns (e.g., *species, series*), both *simplicus* and *compositum* are treated as invariant in plural form.

decisive break, expanding dialectic from a method into a comprehensive logic of becoming.

From Hegel to Marx and Engels, dialectic underwent both inversion and extension: it was turned toward materialism and applied beyond logic to history and nature (Ollman, 1993). Engels, in particular, argued that one of Hegel's key claims — the transformation from quantity to quality — could be treated as a universal law of motion in nature (Engels [1878] 1969; Engels [1883] 1976). The idea is that accumulation of quantitative change produces qualitative novelty, as when "more of the same" eventually yields something categorically different. This formulation has been especially influential in Marxist traditions, where it is often treated not as a heuristic but as a law of nature — a usage more characteristic of nineteenth-century science than of today [2].

The central question of this article is whether such a claim is scientifically tenable. To clarify, by a "dialectical leap" we mean three interrelated criteria:

(1) **Ontological discontinuity**, irreducible to a continuous gradient;
(2) **Qualitative novelty**, the emergence of a new kind rather than a mere modification; and
(3) **Internal causation**, arising from contradictions within the system rather than external triggers.

These criteria distinguish dialectical leaps from threshold phenomena already known in science.

It is important to note that the critique developed here does not apply to dialectic as a method of inquiry, argumentation, or conceptual clarification, from Socratic dialogue to Kantian critique, nor even to many aspects of Hegel's philosophical system. Instead, the focus is precisely on the strong-form claim — articulated by Hegel and codified by Engels in *Dialectics of Nature* — that dialectic, through the

[2] The concept of a "law of nature" carried different connotations across historical periods. In the seventeenth and eighteenth centuries, laws were often conceived as universal, even divine, prescriptions governing reality, as in Galileo and Newton. By the nineteenth century, this metaphysical sense persisted, which helps explain Engels's confidence in formulating "laws of dialectics" as natural-scientific principles. In the twentieth century, however, the term came under greater scrutiny: philosophy of science increasingly treated laws as descriptive regularities rather than necessary structures (see van Fraassen, 1989; Carroll, 1994), and scientific practice shifted toward models, mechanisms, and statistical descriptions (Cartwright, 1983). This broader decline in the invocation of "laws" partly reflects the move away from deterministic worldviews.

"quantity-to-quality" transformation, constitutes a universal law governing natural processes.

This article evaluates whether the Hegel–Engels claim that quantitative accumulation generates qualitative transformation through internal contradiction is supported by empirical evidence in nature.

# 3. Framing the Problem

In the first article of this series, I examined how various 20th-century thinkers — notably Adorno and Žižek — transformed or removed essential building blocks of dialectic, including contradiction, immanence, and ontological necessity. As a result, their use of the term "dialectic" becomes increasingly metaphorical and conceptually unmoored. Likewise, some thinkers (e.g., Levins & Lewontin, 1985; Sheehan, 2018) invoke dialectical-sounding language such as reciprocity or dynamic interdependence, but without the presence of internal contradiction or endogenous causality. These uses may have rhetorical or heuristic appeal, but they fall outside the strict dialectical framework under scrutiny here. What follows, then, is a critique not of dialectic in the loose or metaphorical sense, but of a strong-form claim: that internal contradiction drives qualitative transformation in nature. It is this claim, not its diluted variants, that I examine on scientific grounds.

The principle of quantitative-to-qualitative transformation originates most explicitly in Hegel's *Science of Logic* (1812–1816), where he asserts that "quantity is sublated in quality" [3] when an accumulation results in a fundamental change of kind [4]. This

[3] Hegel redefines dialectic as a generative principle operative both in the foundation of philosophical systems and in the unfolding of actual historical reality. In his *Science of Logic*, dialectic is no longer merely a method of reasoning; it becomes the internal structure of the very process through which concepts develop. This development occurs through contradiction, negation, and sublation (*Aufhebung* = [negation + preservation + elevation]) (Hegel [1812–1816] 2010).

[4] Two short passages from Hegel illustrate the framework for the "shift from quantity to quality." *The Science of Logic*. Translated by George Di Giovanni (2010), Cambridge University Press:

- §367: "As it alters in temperature, it does not become just more or less warm, but passes through the states of solid, liquid, and vapor; and these different states do not occur gradually, but, on the contrary, even the otherwise merely gradual increase in temperature is interrupted and inhibited at these points: the irruption of another state is a leap. – Every birth and every death, far from being a protracted gradualness, is rather its breaking off and a leap from quantitative into qualitative alteration."
- §368: "*Natura non facit saltum*, as the saying goes; and ordinary thinking, when confronted by a coming-to-be or a passing-away, believes that it has comprehended it conceptually by

idea was later reformulated by Friedrich Engels in *Dialectics of Nature* (1883), where it appears as one of the three "laws of dialectics." Engels presented these laws not merely as philosophical insights but as laws of development in nature itself, valid for theoretical natural science as well as thought. To illustrate, he used examples from physics and chemistry, such as the boiling and freezing of water or the magnetization of iron, treating these transitions as paradigmatic cases of dialectical leaps (Engels [1883] 1976).

A noteworthy divergence between Hegel and the Marx–Engels tradition concerns the question of reversibility. In *Science of Logic*, Hegel presents the transformation of quantity into quality as a dialectical movement that can in principle be reversed: qualities can dissolve back into quantitative variation, and the dialectical process oscillates through sublation. By contrast, Marx and Engels treated the principle as an irreversible law of development, where once a new quality has emerged, it marks a definitive stage that cannot revert to the prior one. Engels' reliance on examples such as water's phase transitions and the incandescence of metals is thus peculiar: both are in fact reversible under changes of temperature and pressure, yet Engels insisted on irreversibility as a universal feature of dialectical transformation. This tension complicates the attempt to apply the principle consistently across natural and social domains.

Though grounded in metaphysical reflection, Engels explicitly framed the principle as a scientific law, generalizing it beyond philosophy to natural processes. It has since been invoked in Marxist theory (Ollman, 1993) to explain revolutionary breaks in social development, and more recently linked to complexity theory or systems transitions. This universal ambition makes the principle vulnerable to empirical scrutiny.

The key issue is this: Does a transition in behavior or structure — whether physical, chemical, or social — necessarily imply a dialectical leap caused by an internal contradiction? Or can all such transformations be described in terms of continuous, quantifiable processes already modeled by modern science? To evaluate the validity of dialectical leaps, we must examine not only the occurrence of qualitative transformations but also the causal mechanisms driving them.

representing it, as we said, as a gradual emerging or vanishing. But we have seen that the alterations of being in general are not only the passing over of a magnitude into another magnitude, but the transition from the qualitative into the quantitative and contrariwise, a becoming-other that interrupts gradualness and stands over against the preceding existence as something qualitatively other."

The question of internal contradiction leads us to a second core feature of dialectical transformation: immanence. In dialectical logic, especially as developed by Hegel and extended by Marx (Engels [1878] 1969; Ollman, 1993; Houlgate, 2005), the transformation from one state to another must arise from within — from a contradiction inherent to the structure of the system itself. It is not enough for change to occur; the cause must be endogenous, driven by contradictions internal to the object under consideration.

This raises a methodological challenge: What would count as a genuinely immanent transformation in the natural world? The subsequent sections (5.1–5.7) test this claim across notable examples. If all known transformations can be explained through external inputs, stochastic fluctuations, or structural thresholds without appeal to contradiction, then immanence as a scientific category is undermined.

The problem under investigation is whether natural transformations genuinely arise from internal contradictions (immanence) and thus warrant dialectical interpretation, or whether they can be fully explained without recourse to dialectical leaps.

# 4. Methodological Standards

In assessing dialectical claims against scientific phenomena, we employ the following methodological criteria. These standards refine the three criteria of a dialectical leap (discontinuity, novelty, immanence) into operational tests suitable for scientific evaluation:

- **Continuity vs. Discontinuity** — Is the transformation smooth and gradual, or abrupt and ruptural?
- **Internal vs. External Causation** — Does the system change because of internal contradiction, or due to external influences?
- **Novelty** — Does the transformation yield a qualitatively new state, irreducible to prior states?
- **Predictive Models** — Can the process be accounted for by established scientific models (quantitative or mechanistic)?
- **Conceptual Coherence** — Does the description rely on clearly defined, testable concepts rather than vague metaphor?

These criteria allow us to test whether dialectical principles add genuine explanatory value, or whether observed transformations can be fully captured within existing scientific frameworks [5].

# 5. Refutations of notable examples

In this section, seven prominent examples often cited to support the dialectical transition from quantity to quality are examined. The analysis draws from the works of Hegel, Engels, and the paleobiologists Gould and Eldredge.

The cases fall into three groups:

- **Hegel's examples**: phase transitions of water; incandescence in metals.
- **Engels' examples**: magnetic polarity reversal; allotropy; hydrocarbon chain extension; the periodic table.
- **Evolutionary biology (20th century)**: punctuated equilibrium, as proposed by Gould and Eldredge.

These cases are shown to be either illusory, externally mediated, or reducible to continuous, mechanistic processes that undermine the dialectical model.
The classic examples used to defend the dialectical leap fail to meet scientific scrutiny and instead reveal continuous, externally mediated processes.

[5] The choice of methodological standards reflects debates in the philosophy of science. Thinkers such as Popper, Hempel, and Cartwright focus on *simplicus* criteria — single building blocks like falsifiability, law-based explanation, or models. By contrast, Lakatos offers a *compositum* framework in his theory of research programs, which integrates multiple elements (hard core, protective belt, heuristics, historical progression). Since six of the seven scientific examples examined in Section 5 involve single, isolated standards (*simplicus*), we primarily adopt the corresponding criteria here, while acknowledging Lakatos as an exception.

Kuhn, though often invoked in discussions of scientific change, is excluded here for two reasons. First, his account of paradigm shifts is sociological and historical rather than methodological or ontological, and thus falls outside the scope of this article. Second, while some thinkers — most notably Stephen Jay Gould — have interpreted Kuhn through a Marxist or dialectical lens, such readings reinforce the metaphorical rather than scientific character of "dialectical leaps." Gould's punctuated equilibrium (see Section 5.7), for example, borrows from dialectical motifs of discontinuity and novelty, but its empirical application remains a biological hypothesis rather than a methodological standard. Thus, Kuhn and his sociological successors highlight the rhetorical appeal of dialectical imagery but do not provide methodological criteria relevant to the evaluation of natural-scientific claims.

## 5.1 Water Phase Transition

The phase transition of water — boiling or freezing — has often been cited as a textbook case of a "qualitative leap." Hegel referred to such phase changes as nodal points in nature, and Engels treated them as confirmation of the principle that quantitative accumulation inevitably produces qualitative transformation.

Yet the example is inconsistent with their own principle. The decisive factor is not any accumulation of water's own quantity, but the application of external heat or cooling. If dialecticians claim that mere accumulation of water could eventually generate heat and thus lead to vaporization, then the counter-question follows: would removing some quantity of water likewise generate freezing into ice? Such a claim would be absurd. Moreover, even the suggestion that accumulated water could self-generate heat requires hidden external factors (such as compression or friction), which again undermines the dialectical reading.

Modern science makes this clearer. A single $H_2O$ molecule floating in space will never undergo a phase transition, no matter how much heat it absorbs [6]. Phase change is not intrinsic to water itself but a collective phenomenon that arises only when many molecules interact under specific external conditions such as density, pressure, or confinement. What appears as a sudden leap is in fact a threshold-dependent process, externally mediated and statistically governed.

The phase change of water depends on external factors and collective conditions, not on an intrinsic dialectical leap.

## 5.2 Incandescence in Metals

The incandescence of metals is often presented as a case of "quantity becoming quality." As a wire is heated, it seems to pass from dark to red, orange, and finally white-hot. Engels treated this as a natural confirmation of dialectical logic: the accumulation of thermal energy (quantity) appearing to yield a new visible property (quality).

[6] Another way to see this is to imagine molecular aggregation in intergalactic space. Such aggregation requires external forces, such as planetary gravity, and at near absolute zero the resulting ice mass would remain inert, generating no heat on its own. Only if the mass reached extreme sizes (100–400 km in diameter) could compression begin to raise temperature. Even here, external mediation is decisive, not internal contradiction.

Yet the example fails on its own terms. The decisive factor is not any internal accumulation, but the external application of heat. The apparent jumps between red, orange, and white are not ruptures in the metal itself but thresholds of human visual perception. A simple spectrometer shows that the emitted light changes continuously with temperature. Hegel and Engels overlooked an obvious inconsistency: their supposed leap rests on perceptual illusion, not on internal contradiction [7].

Modern physics makes this explicit. According to Planck's radiation law (Planck, 1901), the emission spectrum of a heated object broadens smoothly as temperature rises, shifting toward shorter wavelengths. Other thermodynamic relations, such as the Stefan–Boltzmann and Wien laws, confirm the same continuous pattern. The metal's electronic structure remains unchanged; only the distribution of emitted photons varies with lattice vibrations. What seems abrupt to the naked eye is revealed, under measurement, to be a continuous radiative process.

The color change in heated metals reflects continuous radiation and perceptual thresholds, not a dialectical leap.

## 5.3 Magnetic Polarity Reversal

Engels pointed to the phenomenon of magnetic polarity reversal as a case of "quantity becoming quality." When temperature or magnetic field strength increases beyond a certain point, the magnet's orientation appears to flip suddenly. This, he argued, demonstrated a dialectical leap: an accumulation of quantitative change producing a qualitative transformation.

Yet the decisive factor here is again external. Heat from the environment or an imposed magnetic field drives the change; nothing in the magnet itself accumulates an internal contradiction that erupts spontaneously. What looks like a leap is simply the system's response to external conditions, finely tuned by experimental

[7] The physiology of vision reinforces this point. Human eyes perceive color categorically, distinguishing "red" from "orange" even though the underlying radiation spectrum varies smoothly (Lynch & Livingston, 2001). This categorical perception creates the illusion of abrupt transitions. Blackbody radiation curves demonstrate that the shift is in fact continuous across wavelengths.

parameters. Engels overlooked the inconsistency in treating such externally mediated behavior as an immanent dialectical necessity [8].

Modern physics confirms this. Near the Curie temperature, increasing thermal energy gradually disrupts spin alignment until ferromagnetism vanishes (Kittel, 2005; Ashcroft & Mermin, 1976). Likewise, in applied fields, domain walls shift incrementally, with reorientation proceeding by nucleation and propagation (Bertotti, 1998). The apparently abrupt reversal is the macroscopic outcome of many microscopic adjustments, fully described by models such as the Ising framework and the Landau–Lifshitz–Gilbert equations (Brush, 1967; Landau & Lifshitz, 1935; Gilbert, 2004).

Magnetic polarity reversal only appears abrupt; in reality it is a continuous, externally mediated process, and thus fails as an example of a dialectical leap.

## 5.4 Allotropes

Engels cited allotropes as an example of "quantity becoming quality." Carbon, for instance, appears in strikingly different forms — graphite, diamond, graphene — and Engels interpreted these transformations as evidence that mere variation in structure yields a new qualitative kind of matter.

Yet this example suffers from the same inconsistency as the earlier cases. The decisive factor is not any internal contradiction within carbon, but external conditions such as pressure, temperature, and chemical environment. A diamond does not emerge from graphite by internal necessity; it requires extreme pressures and temperatures, whether in the Earth's mantle or in controlled laboratory conditions. Engels overlooked the fact that these transformations depend entirely on external mediation, not on the immanent unfolding of quantity into quality.

Modern chemistry confirms this. The conversion from graphite to diamond involves a reconfiguration of bonding geometries, from planar $sp^2$ to tetrahedral $sp^3$

[8] A second way to refute the dialectical reading is to note the probabilistic nature of domain reorientation. Microscopic domains respond stochastically to external influences; only when aggregated at scale do they produce the impression of a sudden flip. The "leap" is therefore a perceptual artifact of collective behavior, not the eruption of internal contradiction.

hybridization [9]. This shift demands external intervention to overcome large activation energy barriers and is fully explained by molecular orbital and crystal field theory (Atkins & Friedman, 2010; Ballhausen, 1962). Moreover, many allotropic transformations are reversible — as in the case of ozone and dioxygen — which undermines the idea of a one-directional dialectical leap toward a "higher" stage [10].

Allotropy demonstrates externally conditioned structural variation, not a dialectical leap arising from internal contradiction.

## 5.5 Hydrocarbon Addition

Engels cited the hydrocarbon series as an empirical illustration of "quantity becoming quality." By gradually adding $CH_2$ groups, hydrocarbons progress from gases (methane, ethane) to liquids (pentane, hexane) to waxy solids (paraffins). Engels treated this as a clear case of molecular quantity producing a qualitative shift in phase.

But the logic here does not hold. The decisive factor in these transitions is not an internal contradiction within the hydrocarbon molecule but external conditions of temperature and pressure. A molecule does not become a liquid or solid simply by virtue of "adding more of the same." Rather, whether methane, pentane, or paraffin, the phase depends on surrounding environmental parameters. Engels overlooked the fact that what appears as a leap is in fact a gradual adjustment governed by external mediation.

Contemporary chemistry confirms this. The transition from gas to liquid to solid in homologous hydrocarbon series is explained by London dispersion forces [11], which

[9] The notations "$sp^2$" and "$sp^3$" refer to the hybridization of s and p orbitals in a carbon atom. Orbitals are cloud-like regions surrounding atoms where the probability of finding electrons is highest. (See also the personal note on orbitals in Section 5.6.)

[10] Here one may recall the difference between Hegelian and Engelsian dialectics. Hegel even considered the relation between "birth and death" to be reversible (see Section 3, footnote with Hegel quotation). This reflects how Hegel's dialectic is shaped by conceptual mediation, while Engels ties it to empirical claims about nature.

[11] London dispersion forces are weak intermolecular attractions caused by correlated fluctuations in electron distributions. They grow with molecular surface area and polarizability, explaining why larger hydrocarbons condense more readily than smaller ones. A supplementary perspective comes from nucleation theory: in hydrocarbon condensation (e.g., in hydrocarbon clouds), phase change begins in localized microdomains, not in a single abrupt shift. Tiny molecular clusters form gradually, stabilized by ambient pressure or cooling, and only become macroscopically visible once they coalesce. This illustrates how the supposed "leap" is actually a threshold effect of aggregation.

scale smoothly with molecular size and surface area (Israelachvili, 2011). As $CH_2$ units accumulate, boiling and melting points rise incrementally, producing different observable phases under standard conditions. What seems to be an abrupt transformation is simply the outcome of continuous variation in intermolecular interactions, fully accounted for by statistical mechanics and thermodynamics (McQuarrie & Simon, 1997).

Hydrocarbon phase changes result from continuous intermolecular scaling under external conditions, not from an intrinsic dialectical leap.

## 5.6 Periodic Table

Engels treated the periodic table as a demonstration of quantity turning into quality. As atomic weights increase, he argued, new chemical properties emerge, and Mendeleev's successful prediction of undiscovered elements seemed to confirm the dialectical principle of nodal transformation.

But this interpretation overlooks the decisive point: the emergence of chemical properties is not an immanent leap within matter but the outcome of external structural constraints. Each element differs from the previous one by exactly one proton and one electron, and their behavior is determined by how electrons occupy available orbitals. The periodic table thus reflects a mathematical ordering, not the eruption of internal contradiction. Engels misread what is, in fact, a systematic quantum pattern as a dialectical rupture.

Modern science makes this plain. The properties of the elements arise from electron configuration governed by the Pauli exclusion principle [12] (Pauli, 1925), Hund's rule (Hund, 1927), and the Schrödinger equation (Schrödinger, 1926). Periodicity in reactivity, ionization energy, and bonding is a consequence of orbital filling, a smoothly scaling process with no sudden break. On the cosmic scale, the origin of

[12] There are certain things which, once they settle in the mind, never leave it. In high school chemistry, our teacher explained the Pauli exclusion principle. What he told us (it must have been around 1969 or 1970) was this: if an atomic energy level contains more than one orbital, then no orbital can hold two electrons unless all others contain at least one. At that instant, I realized I was a socialist. The modern formulation is: "no two electrons can occupy the same quantum state." From this definition one can even draw a metaphor of diversity leading toward democracy. A second time I realized I was a socialist was when our geology teacher said: "The ultimate goal of all flowing water is the complete leveling of the Earth's surface." Honor to all teachers! Of course, scientific laws are not political doctrines, but they can serve as metaphors that illuminate ethical intuitions.

the elements reinforces the same point: after the Big Bang produced hydrogen and helium, heavier nuclei were synthesized gradually in stars through fusion, up to iron (Burbidge et al., 1957), and beyond iron through supernovae and neutron-star collisions, where extreme conditions enabled rapid neutron capture (Kratz et al., 2007). These processes depend entirely on external astrophysical environments — gravity, pressure, temperature — not on any self-contradictory drive within hydrogen or helium atoms.

The periodic "law" and the cosmic origin of elements are fully explained by quantum mechanics and astrophysics; they reveal patterned continuity shaped by external conditions, not dialectical leaps from quantity into quality.

## Bridge: From Classical Examples to a New Example

Given the evident failure of the classical examples (Sections 5.1–5.6), one might expect the idea of a dialectical leap or rupture to have long been abandoned as unsubstantiated, surviving only in the most traditional Marxist circles. Yet the notion has retained a curious charm. In fact, some contemporary thinkers have continued to fashion new theories upon the model of the dialectical leap.

Even more strikingly, the imagery of sudden rupture has traveled well beyond philosophy and natural science. Variants of the model appear in social theory and public policy (e.g., accounts of long stasis interrupted by sudden reform), in evolutionary economics (where equilibria and discontinuities are used to frame market dynamics), and in theoretical modeling more broadly, where complex systems are sometimes described in terms borrowed from dialectical or quasi-dialectical imagery [13].

Something that should never have inspired new theoretical constructions — given its lack of rigor and repeated refutations — has nevertheless generated further attempts to recast the dialectical leap. The most notable of these is the twentieth-century theory of punctuated equilibrium, to which we now turn.

---

[13] For example, in political science, Baumgartner and Jones (1993) introduced a "punctuated equilibrium" model of public policy, emphasizing long periods of stability disrupted by sudden bursts of change. Similar formulations appear in evolutionary economics, where concepts such as multiple equilibria and discontinuous shifts are invoked to describe market dynamics.

## 5.7 Punctuated equilibrium

The theory of punctuated equilibrium, introduced by Stephen Jay Gould and Niles Eldredge in the 1970s, challenged the Darwinian picture of slow, gradual change. According to their model, species persist in long periods of relative stasis, interrupted by comparatively brief episodes of rapid change during which new species appear (Eldredge & Gould, 1972). The fossil record, with its frequent gaps and abrupt transitions, was taken as evidence in support of this view. Gould later framed this explicitly in dialectical terms, treating the "punctuations" as evolutionary leaps (Gould, 2002).

Yet this interpretation misrepresents the processes at work. From a philosophical standpoint, punctuated equilibrium does not involve an internal contradiction within species that suddenly erupts into novelty. Rather, it depends on external and contingent conditions: small, isolated populations, specific ecological pressures, and the probabilistic accumulation of genetic changes. What looks like a rupture in the fossil record is an artifact of scale and resolution, not a dialectical leap.

Modern genetics and systems biology confirm this. Mutations accumulate gradually across many loci, most having little effect in isolation. Only in rare cases does a further mutation tip the balance, producing a visible trait that may spread if environmental conditions allow. In small populations, such changes can rise to prominence through drift and selection, but this remains a cumulative process unfolding over time. The fossil record, with its gaps, makes such gradual origins invisible and creates the illusion of suddenness. Detailed accounts from metabolic control analysis (Kacser & Burns, 1973; Heinrich & Rapoport, 1974) reinforce this probabilistic and distributed character of biological change [14].

Thus, punctuated equilibrium does not vindicate the Hegelian or Engelsian principle of quantity transforming into quality. It exemplifies how complex, gradual processes can appear discontinuous at coarse scales of observation. The "punctuations" are products of population dynamics and incomplete records, not dialectical ruptures.

---

[14] For an extended discussion of how Metabolic Control Analysis (MCA) illustrates the distributed, gradual character of biological change — including analogies and experimental evidence — see Appendix A.

## 5.8 Pseudo-dialectical examples

A final category concerns thinkers who invoke the language of dialectic but use it in ways that no longer meet the conceptual criteria under discussion here. Among these are Richard Levins and Richard Lewontin, whose *Dialectical Biology* (1985) became the cornerstone of "dialectical biology," and more recent authors such as Sheehan (2018), who link dialectical motifs with complexity science. While these contributions have been influential in their own domains, they rely on a broadened and metaphorical sense of dialectic that diverges from the standards of contradiction, immanence, and qualitative leap that guide the present critique.

Levins and Lewontin's definition of "system" is so expansive that virtually every process can be treated as "internal" to it. This rhetorical move renders the notion of *internal contradiction* analytically empty: if all external influences can be redescribed as internal relations, the distinction between inner dynamic and outer mediation collapses. Similarly, by equating any dynamic or reciprocal process with dialectics, they effectively conflate *dialectic* with *systems theory* or *cybernetic feedback*. While such models are useful, they are not dialectical in the Hegelian or Engelsian sense [15].

Further, their framework does not provide an account of *qualitative leaps* in the strict sense. Their treatment of biological change emphasizes co-determination, mutual interaction, and historical contingency — all valid scientific concepts — but none of these amount to the dialectical principle of quantity turning into quality through contradiction. Instead, what we find are continuous adaptive processes that can be adequately explained without recourse to dialectical categories.

Sheehan (2018) [16] takes this trend further by aligning dialectic with complexity science. Here, "dialectic" becomes a synonym for emergence, nonlinearity, or multi-level causation. These notions, though valuable in their own right, are fully explicable within the methodological frameworks of systems biology, network

---

[15] Some Marxist commentators defend this broadened usage by arguing that "dialectic" should be understood as a general ontology of relationality or process. From this perspective, Levins and Lewontin's assimilation of external factors into "internal" relations is not a distortion but an expansion. The difficulty with this defense, however, is that it erases the specificity of dialectical contradiction. If everything dynamic is dialectical, then the term becomes indistinguishable from "systemic" or "interactive," losing its philosophical edge.

[16] Sheehan's discussion of complexity theory often emphasizes features such as emergence, multi-level causation, and sensitivity to initial conditions. While these are genuine properties of nonlinear systems, they can be adequately modeled by existing mathematical and computational tools without invoking dialectics. In this sense, "dialectic" functions more as a metaphorical flourish than as a necessary explanatory principle.

theory, and nonlinear dynamics. They neither require nor exemplify the dialectical logic of contradiction and leap.

The point is not to diminish the intellectual contributions of these thinkers. Levins and Lewontin, for example, provided enduring insights into ecological modeling, the critique of reductionism, and the role of reciprocal causation in evolution. But these insights are better understood as developments in systems theory and evolutionary biology than as instances of dialectical logic. To conflate the two is to blur categorical distinctions and to misrepresent both traditions.

In short, these “pseudo-dialectical” approaches fall outside the scope of this critique — not because they are dialectical, but precisely because they are not. They exemplify the tendency to expand “dialectic” into a metaphor for dynamism or complexity, thereby losing the conceptual rigor that makes dialectical logic a distinct philosophical position.

Approaches such as dialectical biology and complexity-based “dialectics” are scientifically valuable but philosophically misleading; they mistake systemic dynamics for dialectical contradiction, and thus do not qualify as genuine dialectical models.

## 5.9 Comparative analysis: patterns and divergences

Having reviewed seven prominent examples traditionally cited in support of the dialectical transition from quantity to quality, we can now identify broader patterns in how each fails to meet the dialectical criteria.

In physical systems (e.g., water phase transitions, incandescence, magnetism), transformations are fully governed by external parameters such as pressure, temperature, or field strength. Threshold behavior is real, but it reflects statistical aggregation or perceptual limits rather than contradiction or immanent rupture.

In chemical systems (e.g., allotropy, hydrocarbon chains), changes in structure and properties result from reconfigurations of bonding geometries and intermolecular forces, themselves dependent on environmental conditions. These processes follow clear energetic principles and require external intervention. They exhibit reversibility and continuity, not one-directional dialectical leaps.

In biological systems, especially in the case of punctuated equilibrium, apparent discontinuities in the fossil record emerge from incomplete sampling and resolution limits. The underlying mechanisms — mutation, genetic drift, and selection — operate gradually and probabilistically within ecological contexts. What looks like sudden transformation is the delayed manifestation of cumulative processes in small populations, not an internal contradiction.

Taken together, these cases reveal not a shared dialectical principle but a striking diversity of mechanisms. No single law unites phase transitions, domain wall propagation, atomic reconfigurations, or population genetics. The supposed commonality is imposed retrospectively as a metaphor [17]. If "quantity turning into quality" can be stretched to cover phenomena so heterogeneous, it loses explanatory power and collapses into tautology.

The diversity of physical, chemical, and biological transformations shows that apparent leaps are the outcome of external mediation, gradual accumulation, and probabilistic thresholds — not dialectical contradictions — and thus the principle of "quantity into quality" fails as a general law of nature.

# 6. Philosophical Consequences

Across the examined domains, the supposed "dialectical leaps" turn out, under closer analysis, to be continuous, multivariable processes. Whether in phase transitions, incandescence, magnetic reversals, allotropy, hydrocarbon chains, the periodic table, or speciation, the transformations arise from external mediation, probabilistic aggregation, or thresholds of detectability — not from internal contradiction or logical necessity. The dialectical narrative thus overlays a metaphysical interpretation onto processes that science can already explain in mechanistic and heterogeneous terms.

This cumulative failure has consequences that extend beyond the individual examples. If the most frequently cited illustrations collapse under contemporary scrutiny, the credibility of the *quantity-to-quality* principle itself is undermined. The issue is not that Engels or Hegel chose the wrong cases; rather, the principle lacks explanatory precision. Natural systems show distributed causation, gradual

[17] Over-extension of dialectical categories risks dissolving them into metaphorical language. By treating any change as a "leap," dialectics ceases to function as an explanatory framework and becomes an interpretive overlay, applicable everywhere but illuminating little.

transitions, and external constraints — not abrupt ruptures generated by immanent contradiction.

At the same time, one might argue that dialectical categories are not meant to compete with scientific mechanisms, but to serve as heuristic metaphors for complexity and change. This softer reading preserves dialectic as a rhetorical or pedagogical device, but at the cost of abandoning its claim to identify "universal laws of motion." If dialectic is to retain philosophical value, it must be acknowledged as a style of thought rather than as a binding ontology.

From the perspective of the philosophy of science [18], this aligns more with critical rationalism (Popper, 1959; 1963) and research-program methodologies (Lakatos, 1978), where explanatory frameworks stand or fall by empirical resilience and coherence, not metaphysical resonance. On this view, the dialectical leap adds little to scientific explanation: it overstates the role of contradiction and understates the roles of contingency, environment, and probability. The burden rests not on those who deny the leap, but on those who continue to assert it.

# 7. Conclusion

The cumulative failure of the examined cases reveals a deeper flaw in the dialectical framework itself. Its central claim — that quantitative accumulation yields qualitative transformation through internal contradiction — collapses under scrutiny not simply because Engels or Hegel chose weak examples, but because no consistent mechanism unites them. What the dialectical narrative treats as logical necessity is, in scientific terms, nothing more than threshold effects, contextual shifts, or perceptual limits.

The supposed "leap" obscures rather than illuminates. Physical, chemical, and biological systems display reorganization, thresholds, and discontinuities, but these emerge from external mediation, probabilistic causation, and distributed

[18] My broader position on the philosophy of science is elaborated elsewhere (see: https://hosseinjorjani.com/philosophy-history-and-methods-of-sciences-1/). In brief: I regard scientific theories as either simplicus or compositum (as defined earlier: *simplicus* denotes a non-composite theoretical structure; *compositum* a composite one, both treated as invariant in the plural). With respect to simplicus theories, my stance is broadly aligned with traditions of critical rationalism (in which Karl Popper figures prominently), emphasizing testability and falsifiability. For compositum theories, I find greater affinity with frameworks influenced by Thomas Kuhn, which highlight paradigm-dependence and historical contingency. The common thread is that explanatory value derives not from metaphysical necessity but from empirical resilience, coherence, and openness to revision.

interactions. The dialectical interpretation misrepresents this complexity by collapsing causal diversity into a single metaphysical template. It offers narrative unity where science requires explanatory precision.

This failure has broader implications. Defenses of dialectic in philosophy, politics, or social theory often lean on analogies with nature: dialectic is said to mirror reality because reality itself is dialectical. But if the natural world provides no genuine examples of dialectical leaps, then this foundational analogy collapses. Worse, the argument often turns circular: nature is read as dialectical to validate dialectic, and dialectic is then applied to interpret nature and society, which in turn supposedly confirms the method. Once this loop is broken, dialectic loses its evidentiary footing.

Rejecting the leap does not mean rejecting development, contradiction, or systemic analysis. It means rejecting the claim that change is driven by immanent negation rather than by mechanisms, conditions, and contingencies. Scientific explanation today requires fine-grained models supported by evidence, not metaphysical imperatives imposed in advance.

If dialectic is to remain relevant, it must renounce its ambition to legislate nature from within and accept a humbler role: not as a law of transformation, but as a metaphor among others — a perspective open to revision like everything else. Nature does not obey contradiction; it obeys mechanisms.

# 8. Summary of the next section

**Part 3** of this article series maintains that not all systemic transformations are dialectical, and many that appear so are quasi-dialectical transformations, better explained by several other concepts, one of which is scale-dependent thresholds. To untrained eyes, quasi-dialectical transformations have a rudimentary resemblance to the Hegel-Engels dialectic, while they do not fulfil its requirements. Drawing from domains as varied as urban design, biological stability, artificial intelligence, and enzymatic systems, the article presents six cases of quasi-dialectical transformation. These transitions exhibit sharp discontinuities and systemic reorganization, yet remain intelligible without resorting to dialectical metaphysics. The article concludes by exploring the role of Inference to the Best Explanation (IBE) as a model for evaluating competing frameworks, and argues for a rethinking of dialectic not as a universal method but as one explanatory strategy among others.

# 9. References


Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2002). Molecular biology of the cell (5th ed.). Garland Science.

Allison, H. E. (2004). *Kant’s Transcendental Idealism* (Rev. ed.). Yale University Press.

Armstrong, A. H. (Trans.). (1966–1988). *Plotinus* (7 vols.). Loeb Classical Library.

Atkins, P., & de Paula, J. (2014). *Physical Chemistry* (10th ed.). Oxford University Press.

Atkins, P. W., & Friedman, R. S. (2010). Molecular quantum mechanics (5th ed.). Oxford University Press.

Ashcroft, N. W., & Mermin, N. D. (1976). Solid state physics. Holt, Rinehart and Winston.

Ballhausen, C. J. (1962). Introduction to ligand field theory. McGraw-Hill.

Bertotti, G. (1998). Hysteresis in magnetism: For physicists, materials scientists, and engineers. Academic Press.

Bohren, C. F., & Huffman, D. R. (2008). *Absorption and Scattering of Light by Small Particles*. Wiley.

Brush, S. G. (1967). History of the Lenz-Ising model. Reviews of Modern Physics, 39(4), 883-893.

Bundy, F. P., Bassett, W. A., Weathers, M. S., Hemley, R. J., Mao, H. K., & Goncharov, A. F. (1996). The pressure-temperature phase and transformation diagram for carbon; updated through 1994. Carbon, 34(2), 141-153.

Burbidge, E. M., Burbidge, G. R., Fowler, W. A., & Hoyle, F. (1957). Synthesis of the elements in stars. Reviews of Modern Physics, 29(4), 547-650.

Buseck, P. R., & Huang, B. J. (1985). “Conversion of carbonaceous material to graphite during metamorphism.” *Geochimica et Cosmochimica Acta*, 49(10), 2003–2016.

Butterworth, C. E. (2007). *Averroes' Middle Commentary on Aristotle's Topics*. SUNY Press.

Carroll, B. W., & Ostlie, D. A. (2017). *An Introduction to Modern Astrophysics* (2nd ed.). Cambridge University Press.

Chandler, D. (1987). *Introduction to Modern Statistical Mechanics*. Oxford University Press.

Chikazumi, S. (2009). *Physics of Ferromagnetism* (2nd ed.). Oxford University Press.

Cowan, J. J., Sneden, C., Lawler, J. E., et al. (2021). Origin of the heaviest elements: The rapid neutron-capture process. *Reviews of Modern Physics*, 93(1), 015002.

Cullity, B. D., & Graham, C. D. (2011). *Introduction to Magnetic Materials* (2nd ed.). Wiley-IEEE Press.

Dash, J. G., Rempel, A. W., & Wettlaufer, J. S. (2006). The physics of premelted ice. *Reviews of Modern Physics*, 78(3), 695–741.

Debenedetti, P. G. (1996). *Metastable Liquids: Concepts and Principles*. Princeton University Press.

Eldredge, N., & Gould, S. J. (1972). Punctuated equilibria: An alternative to phyletic gradualism. In T. J. M. Schopf (Ed.), Models in paleobiology (pp. 82-115). Freeman, Cooper and Company.

Engels, F. ([1878] 1969). Anti-Dühring: Herr Eugen Dühring's Revolution in Science (E. Burns, Trans.). Progress Publishers.

Engels, F. ([1883] 1976). Dialects of Nature. (In complete works; e.g., Marx & Engels, Collected Works, Vol. 27). International Publishers.

Eyre-Walker, A., & Keightley, P. D. (2007). The distribution of fitness effects of new mutations. Nature Reviews Genetics, 8(8), 610-618.

Frenkel, D., & Smit, B. (2002). *Understanding Molecular Simulation: From Algorithms to Applications*. Academic Press.

Gaukroger, S. (1995). *Descartes: An Intellectual Biography*. Clarendon Press.

Gaukroger, S. (2006). The Emergence of a Scientific Culture: Science and the Shaping of Modernity 1210–1685. Oxford University Press.

Gilbert, T. L. (2004). A phenomenological theory of damping in ferromagnetic materials. IEEE Transactions on Magnetics, 40(6), 3443-3449.

Gould, S. J., & Eldredge, N. (1977). Punctuated equilibria: the tempo and mode of evolution reconsidered. Paleobiology, 3(2), 115–151.

Gould, S. J. (2002). *The structure of evolutionary theory*. Belknap Press of Harvard University Press.

Gutas, D. (2001). *Avicenna and the Aristotelian Tradition*. Brill.

Hegel, G. W. F. ([1812–1816] 2010). *Science of Logic*. (Trans. George Di Giovanni). Cambridge University Press.

Heinrich, R., & Rapoport, T. A. (1974). A linear steady-state treatment of enzymatic chains. European Journal of Biochemistry, 42(1), 89-95.

Hemley, R. J., & Mao, H. K. (1991). "High-pressure chemistry of the Earth's interior." *Science*, 253(5022), 746–751.

Houlgate, S. (2005). *An Introduction to Hegel*. Blackwell.

Howell, J. R., Siegel, R., & Mengüç, M. P. (2015). *Thermal Radiation Heat Transfer* (6th ed.). CRC Press.

Hund, F. (1927). Zur Deutung der Molekelspektren. Zeitschrift für Physik, 40(10), 742-764.

Israelachvili, J. N. (2011). *Intermolecular and Surface Forces* (3rd ed.). Academic Press.

Kacser, H., & Burns, J. A. (1973). The control of flux. Symposia of the Society for Experimental Biology, 27, 65-104.

Kacser, H., & Burns, J. A. (1979). Molecular Democracy: Who Shares the Controls? Biochemical Society Transactions, 7(5), 1149–1160. https://doi.org/10.1042/bst0071149

Kacser, H., & Burns, J. A. (1981). The molecular basis of dominance. Genetics, 97(3-4), 639–666.

Kant, I. ([1781/1787] 1998). *Critique of Pure Reason*. Cambridge University Press.

Kashchiev, D. (2000). *Nucleation: Basic Theory with Applications*. Butterworth-Heinemann.

Kittel, C. (2005). Introduction to solid state physics (8th ed.). John Wiley & Sons.

Klein, M. L., & Shinoda, W. (2008). Large-scale molecular dynamics simulations of self-assembling systems. Science, 321(5890), 798-800.

Kragh, H. (2002). *Quantum Generations: A History of Physics in the Twentieth Century*. Princeton University Press.

Kratz, K. L., Farouqi, K., & Pfeiffer, B. (2007). Global microscopic calculations of r-process abundances. New Astronomy Reviews, 51(1-2), 80-86.

Ladyman, J. (2002). *Understanding Philosophy of Science*. Routledge.

Ladyman, J., & Ross, D. (2007). Every Thing Must Go: Metaphysics Naturalized. Oxford University Press.

Lakatos, I. (1978). *Philosophical Papers, Vol. 1: The Methodology of Scientific Research Programmes*. Cambridge University Press.

Landau, L. D., & Lifshitz, E. M. (1935). On the theory of the dispersion of magnetic permeability in ferromagnetic bodies. Physikalische Zeitschrift der Sowjetunion, 8, 153-169.

Landau, L. D., & Lifshitz, E. M. (1980). *Statistical Physics, Part 1* (3rd ed.). Butterworth-Heinemann.

Levine, N. (1983). The Engelsian inversion. *Studies in Soviet Thought*, *25*(4), 307–321. https://doi.org/10.1007/BF00838321

Levine, I. N. (2013). *Quantum Chemistry* (7th ed.). Pearson.

Levins, R., & Lewontin, R. (1985). *The Dialectical Biologist*. Harvard University Press.

Lynch, D. K., & Livingston, W. C. (2001). Color and light in nature. Cambridge University Press.

Marenbon, J. (1997). *The Philosophy of Peter Abelard*. Cambridge University Press.

Marx, K., & Engels, F. ([1867] 1976). *Capital, Vol. 1*. Penguin Classics.

McQuarrie, D. A., & Simon, J. D. (1997). Physical chemistry: A molecular approach. University Science Books.

Mitri, G., & Showman, A. P. (2005). Convective-conductive transitions in icy shells. *Icarus*, 177(2), 447–460.

Morris, J. R., Wang, C. Z., Ho, K. M., & Chan, C. T. (1994). “Melting line of aluminum from simulations of coexisting phases.” *Physical Review B*, 49(5), 3109–3115.

Ollman, B. (1993). *Dialectical Investigations*. Routledge.

Ong, W. J. (1958). *Ramus, Method, and the Decay of Dialogue*. Harvard University Press.

Pauli, W. (1925). Über den Zusammenhang des Abschlusses der Elektronengruppen im Atom mit der Komplexstruktur der Spektren. Zeitschrift für Physik, 31(1), 765-783.

Pigliucci, M. (2008). Is evolvability evolvable? Nature Reviews Genetics, 9(1), 75–82.

Planck, M. (1901). "On the Law of Distribution of Energy in the Normal Spectrum." *Annalen der Physik*, 309(3), 553–563.

Planck, M. (1914). *The Theory of Heat Radiation*. Blakiston's Son & Co.

Popper, K. R. ([1934] 1959). *The Logic of Scientific Discovery*. Hutchinson.

Popper, K. R. (1963). *Conjectures and Refutations: The Growth of Scientific Knowledge*. Routledge.

Reif, F. (1965). Fundamentals of statistical and thermal physics. McGraw-Hill.

Rohlf, J. W. (1994). *Modern Physics from α to $Z^0$*. John Wiley & Sons.

Rowlinson, J. S., & Widom, B. (2002). *Molecular Theory of Capillarity*. Dover.

Scerri, E. R. (2007). *The Periodic Table: Its Story and Its Significance*. Oxford University Press.

Schrödinger, E. (1926). An undulatory theory of the mechanics of atoms and molecules. Physical Review, 28(6), 1049-1070.

Seul, M., & Andelman, D. (1995). "Domain shapes and patterns: The phenomenology of modulated phases." *Science*, 267(5197), 476–483.

Sheehan, H. (2018). *Marxism and the Philosophy of Science: A Critical History*. Verso.

Smith, R. (1997). Aristotle on the Dialectical Method. *Phronesis*, 42(2), 147–166.

Spohn, T., & Schubert, G. (2003). Oceans in icy Galilean satellites. *Icarus*, 161(2), 456–467.

Stauffer, A. D., et al. (2014). "Thermal emission and radiation thermometry: evolution of principles and practices." *Metrologia*, 51(5), S122–S132.

Stump, E. (2003). *Aquinas*. Routledge.

Suppe, F. (Ed.). (1977). *The Structure of Scientific Theories* (2nd ed.). University of Illinois Press.

Vlastos, G. (1994). *Socratic Studies*. Cambridge University Press.

Wagner, A. (2005). Robustness and Evolvability in Living Systems. Princeton University Press.

White, N. P. (1971). Plato's Metaphysics of Education. *Philosophy and Phenomenological Research*, 32(1), 30–44.

Wright, S. (1931). Evolution in Mendelian populations. Genetics, 16(2), 97-159.

# Appendix A: Metabolic Control and the Illusion of Evolutionary Leaps

A more precise explanation of this phenomenon, which emerges from the framework of Metabolic Control Analysis (MCA), is that in a saturated system with a large number of enzymes, the effect of each enzyme on the system's final flux generally follows a hyperbolic curve. This means that increasing the activity of a single enzyme, on its own, in most cases cannot lead to a significant increase in final output—unless similar changes occur in the activity of other enzymes as well.

Of course, in classical MCA models, the control coefficient of any given enzyme may be small or large at a particular point in time; but over a long timescale, under conditions of weak selection and environmental stability, these coefficients tend to converge toward relatively stable average values, and nearly all enzymes come to play a role in determining system behavior across generations.

This long-term stability of the averages is, in fact, one of the foundations for the development of stable and "modified" dominance structures in biological systems. As it happens, Wikipedia has a good article on this topic. Even if the reader is not in a position to read the entire article, examining the illustrations provided in the Wikipedia entry can still be beneficial:
(https://en.wikipedia.org/wiki/Metabolic_control_analysis).

To offer an intuitive illustration of this phenomenon, one may refer to a simple example from an automobile factory: increasing the power of a single engine—for instance, doubling its output—does not imply that the number of cars produced will also double. This example, although it involves a logical inconsistency in the type of quantities being compared (power versus count), intentionally introduces that asymmetry in order to highlight an important systemic principle: enhancing the capacity or efficiency of a single component in a complex system does not necessarily lead to a proportional increase in total system output. To double the final output, even components such as mirrors or turn signals must also be scaled up accordingly.

This principle is observable not only in mechanical systems but also in empirical biology: in one of the earliest transgenic experiments, reported in 1982 (Palmiter et al., 1982), the production of growth hormone in mice increased dramatically, yet the final body weight of the mice rose by only about 1.5 times. These findings suggest that in biological systems, the effectiveness of individual components is governed by multivariate control—regulated through internal interactions, external biological constraints, and structural limitations.

On a personal level, until 1991, influenced by my earlier understanding of dialectic, I believed in "revolution" as a theoretical framework. However, in 1991, after reading the article by Kacser and Burns (1979) titled *"Molecular Democracy: Who Shares* *the Controls?"*, which concerns the functional role of enzymes, I began to question the theory of revolution. I ultimately came to the conclusion that a unilateral and abrupt change in one part of a system quickly leads to the breakdown of that system. Conversely, if a small change in one part of a system is gradually accompanied by small changes in its other parts, one may reasonably hope for a transformation of the system as a whole. In the next article in this series, I will refer to "molecular democracy" using the insights of Kacser and Burns (1979).