

Thermodynamics 2.0

# SCIENCE & TECHNOLOGY OF LIFE



T2026  
CONFERENCE

# 2026

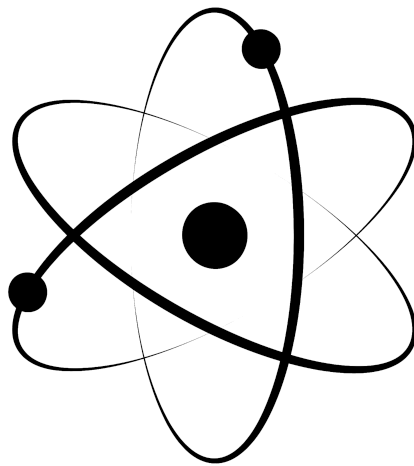


A joint event by



Appalachian  
STATE UNIVERSITY

# Thermodynamics 2.0 | 2026



**International Association for the  
Integration of Science and Engineering**

Broomfield, Colorado, United States

# PROGRAM & BOOK OF ABSTRACT

August 5 - 7, 2026



**International Association for the  
Integration of Science and Engineering**

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## What is Thermodynamics 2.0?

Thermodynamics 2.0 is a platform where the natural sciences meet the social sciences.

Thermodynamics offers a universal framework for understanding many natural phenomena. Thermodynamics 2.0 is about the integration of thermodynamics with other academic disciplines such as physics, chemistry, biology, ecology, sociology, economics and more. Thermodynamics 2.0 builds on ideas of Ostwald and Helm, promoted by them as “energetics”. The ideas of energetics have appeared throughout history in many forms, championed by many thinkers. One of its earliest philosophical antecedents can be found in Heraclitus, who proclaimed, 'Everything flows.' The language of Thermodynamics 2.0 is energy or its derivatives such as power, entropy, and information, which could be more fundamental than energy in some ways.

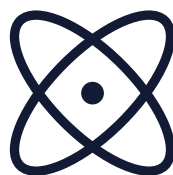
Thermodynamics 2.0 is about reshaping and raising the platform of human knowledge rather than building consensus on how to connect the dots of human knowledge. It is about merging two cultures, not just bridging the gap. We hope to introduce the next generation to the new avenues of thought that thermodynamics has opened in the twenty-first century, and to encourage them to take thermodynamics to the next level. The forthcoming generation will be better prepared and equipped with new and emerging ideas and technology, and will have the advantage of a trove of time-tested ideas awaiting synthesis and unified explanation.

The theme of the Thermodynamics 2.0 | 2026 conference is **Thermodynamic Approach to the Science and Technology of Life**. Pioneers and thought leaders across the disciplines from over 20+ countries will present on the pivotal role thermodynamics can play in connecting the sciences and guiding the evolution of human knowledge.

Thermodynamics 2.0 is an emerging interdisciplinary research program. **T2026** conference provides a forum where researchers from the natural and social sciences come together to explore its implications, opportunities and potential applications.

# ORGANIZERS

Thermodynamics 2.0 | 2026

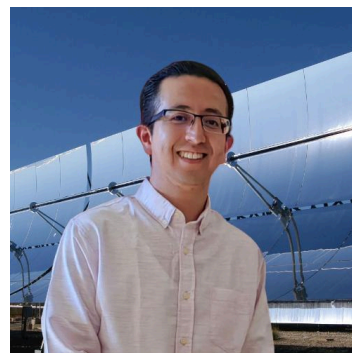


The following IAISAE members have volunteered to help organize the Thermodynamics 2.0 | 2026 conference.



**Ram Poudel**

ORGANIZER

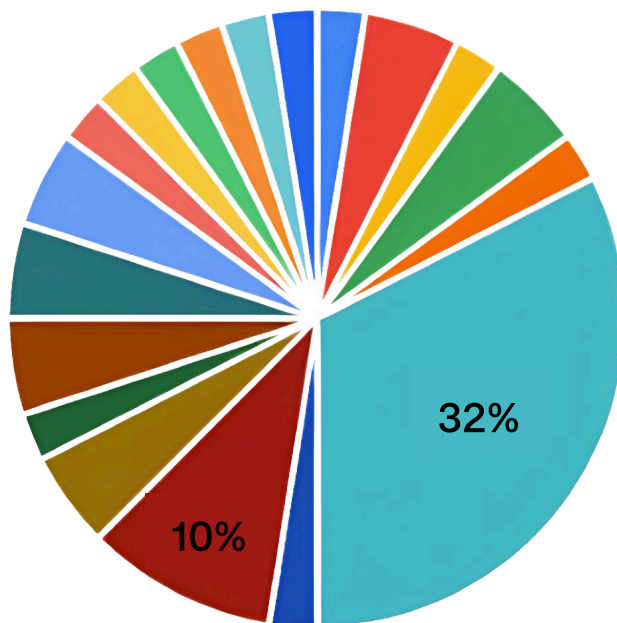


**Eduardo González-Mora**

MEMBER

T2026

# PROGRAM



India Brazil China Canada Venezuela USA Slovenia  
UK Singapore Italy Germany Thailand Japan Mexico  
Nepal UAE Hungary Spain Poland Slovenia

Sessions and Time Table (Eastern Time, USA, UTC -05:00)

Thermodynamics 2.0 | 2026 Conference

| Date → | 4-Aug   | 5-Aug                                                                         | 6-Aug                                                                       | 7-Aug                                                                        | Date                                           |                                                      |               |       |
|--------|---------|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------|------------------------------------------------------|---------------|-------|
| Time ↓ | Tuesday | Wednesday                                                                     | Thursday                                                                    | Friday                                                                       | Time                                           |                                                      |               |       |
| 9:00   |         | Welcome and Opening Remarks                                                   | Keynote and Plenary II:<br><br><b>Jeremy Schmit</b><br><b>Yasar Demirel</b> | Keynote and Plenary III:<br><br><b>Terry Bristol</b><br><b>Umberto Lucia</b> | 9:00                                           |                                                      |               |       |
| 9:15   |         | Keynote and plenary I:<br><br><b>Sunil Nath</b><br><b>Constantino Tsallis</b> |                                                                             |                                                                              |                                                | 9:15                                                 |               |       |
| 9:30   |         |                                                                               |                                                                             |                                                                              |                                                |                                                      | 9:30          |       |
| 9:45   |         |                                                                               |                                                                             |                                                                              |                                                |                                                      |               | 9:45  |
| 10:00  |         |                                                                               |                                                                             |                                                                              |                                                |                                                      |               |       |
| 10:15  |         | Coffee & Networking                                                           | 10:15                                                                       |                                                                              |                                                |                                                      |               |       |
| 10:30  |         |                                                                               | Coffee & Networking                                                         | 10:30                                                                        |                                                |                                                      |               |       |
| 10:45  |         |                                                                               | Marek Frankowicz<br>Yasuko Kawahata<br>Klaus Jaffe                          | 10:45                                                                        |                                                |                                                      |               |       |
| 11:00  |         |                                                                               |                                                                             | Coffee & Networking                                                          | 11:00                                          |                                                      |               |       |
| 11:15  |         | Shripad Mahulikar<br>Pier Luigi Gentili<br>Gregory Yablonsky                  |                                                                             | 11:15                                                                        |                                                |                                                      |               |       |
| 11:30  |         |                                                                               |                                                                             | Terrence Deacon                                                              | 11:30                                          |                                                      |               |       |
| 11:45  |         |                                                                               | Yazdan Pedramrazi<br>Eduardo Gonz-Mora                                      |                                                                              | 11:45                                          |                                                      |               |       |
| 12:00  |         |                                                                               |                                                                             |                                                                              | Lunch Break                                    | 12:00                                                |               |       |
| 12:15  |         | Michael Parker                                                                |                                                                             |                                                                              | 12:15                                          |                                                      |               |       |
| 12:30  |         |                                                                               |                                                                             | Mitch Abrams                                                                 | 12:30                                          |                                                      |               |       |
| 12:45  |         |                                                                               | Open Discussion                                                             | 12:45                                                                        |                                                |                                                      |               |       |
| 13:00  |         |                                                                               |                                                                             | Open Discussion                                                              | Charles Hall &<br>Tim McWhirter                | 13:00                                                |               |       |
| 13:15  |         | Andy LiWang<br>Ramona Luna<br>Tim McWhirter<br>Zuchang Pei                    |                                                                             |                                                                              |                                                | Tamas Matolcsi<br>Lock Yue Chew<br>Van Peter         | 13:15         |       |
| 13:30  |         |                                                                               |                                                                             |                                                                              |                                                |                                                      | IAISAE Awards | 13:30 |
| 13:45  |         |                                                                               |                                                                             |                                                                              |                                                |                                                      | Adjournment   | 13:45 |
| 14:00  |         |                                                                               |                                                                             | 14:00                                                                        |                                                |                                                      |               |       |
| 14:15  |         |                                                                               |                                                                             | 14:15                                                                        |                                                |                                                      |               |       |
| 14:30  |         |                                                                               |                                                                             | Marko Vitas                                                                  | 14:30                                          |                                                      |               |       |
| 14:45  |         |                                                                               |                                                                             |                                                                              | Christine Bizzell                              | 14:45                                                |               |       |
| 15:00  |         |                                                                               | Coffee & Networking                                                         |                                                                              |                                                | 15:00                                                |               |       |
| 15:15  |         |                                                                               | 15:15                                                                       |                                                                              |                                                |                                                      |               |       |
| 15:30  |         |                                                                               |                                                                             | Robert Pepperell<br>Georgi Georgiev<br>Francois Gay-Balmz                    |                                                | Victor Yakovenko<br>Burin Gumjudpai<br>David LACOSTE | 15:30         |       |
| 15:45  |         |                                                                               |                                                                             |                                                                              | 15:45                                          |                                                      |               |       |
| 16:00  |         |                                                                               |                                                                             |                                                                              | 16:00                                          |                                                      |               |       |
| 16:15  |         | 16:15                                                                         |                                                                             |                                                                              |                                                |                                                      |               |       |
| 16:30  |         | Registration<br>Open                                                          | Benjamin DeBari<br>Ram Poudel                                               | Peter Corning<br>Alber Magnell<br>Michael te Vrugt                           | 16:30                                          |                                                      |               |       |
| 16:45  |         |                                                                               |                                                                             |                                                                              | 16:45                                          |                                                      |               |       |
| 17:00  |         |                                                                               |                                                                             |                                                                              | Presenter<br>Technical<br>Success<br>Checklist | Attila Grandpierre                                   | Mickey Maini  | 17:00 |
| 17:15  |         |                                                                               |                                                                             |                                                                              |                                                |                                                      |               | 17:15 |
| 17:30  | 17:30   |                                                                               |                                                                             |                                                                              |                                                |                                                      |               |       |
| 17:45  | 17:45   |                                                                               |                                                                             |                                                                              |                                                |                                                      |               |       |
| 18:00  |         | Summary of the Day:<br>Open Discussion                                        | IAISAE General Meeting                                                      | 18:00                                                                        |                                                |                                                      |               |       |
| 18:15  |         |                                                                               |                                                                             | 18:15                                                                        |                                                |                                                      |               |       |

# Day 1 PROGRAM

Wednesday 5 August, 2026



9:00

## T01: Welcome and Opening Remarks

Ok-Youn Yu, Appalachian State University, Boone, North Carolina

Jon McGowan, University of Massachusetts Amherst, Massachusetts

9:30

## T02: Keynote & Plenary I

**Sunil Nath** Indian Institute of Technology, Delhi

From molecular and cellular bioenergetics to ecology: A thermodynamic approach....

**Constantino Tsallis** Centro Brasileiro de Pesquisas Fisicas, Brazil

Health and Neurosciences – A Nonadditive-Entropy Approach for Diagnosis and More

11:15

## T03: Terrence Deacon (UC Berkeley): Thermodynamic Origin of Molecular Information

12:00

## T04: Luncheon Talk

**Mitchell Abrams** McMaster University, Canada

The Missing Dimension of Modern Healthcare: The Science of Coherence

13:00

## T05: Biosystem Thermodynamics I

**Andy LiWang** University of California, Mearced

Temperature Compensation by the KaiB Protein..Cyanobacterial Circadian Clock

**Ramona Luna** Oregon Health and Science University, Portland

Characterization of Particle Trajectories during Dielectrophoresis Collection and .....

**Timothy McWhirter** Montgomery College, Rockville, Maryland, USA

Energy and Evolution: The Systems Approach

**Zuchang Pei** Independent Researcher

Regulatory Control, Irreversibility, and Major Evolutionary Transitions

14:30

## T06: Thermodynamics of Evolution

**Marko Vitas** Laze pri Borovnici 38, 1353 Borovnica, Slovenia

Evolution, life and cognition through the Lens of Thermodynamics

15:15

## T07: Biosystem Thermodynamics II

**Robert Pepperell** Cardiff Metropolitan University

Experiential Thermodynamics: A Brief Introduction

**Francois Gay-Balmaz** Nanyang Technological University, Singapore

Variational Principles: A Unifying Perspective on Classical and Stochastic Therm

**Georgi Georgiev** Assumption University and Worcester Polytechnic

Exact Evolution Law for Action-Weighted Path Ensembles and the Dynamics of Self-Or

16:30

## T08: Biotechnology Applications

**Benjamin DeBari-Cheung** Thomas Jefferson University, Philadelphia

Self-Organization in Dissipative Systems: Insights for Novel Technologies

17:15

## T09: Attila Grandpierre, Huzhou University, Huzhou, China

The Principle of Greatest Action and the Biological Maximum Principle

18:00

## Open Discussions and Summary of Day 1: Peter Ván

# Day 2 PROGRAM

Thursday 6 August, 2026



|                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-----------------------------------------------|-----------------------------------------------------------------------------|--|---------------------------|----------------------------------------------------|----------------------------------------------------------------------|--|--------------------------|-------------------------------------------------|----------------------------------------------------------------------------------|--|
| 8:45                                                                             | Registration and Networking                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| 9:00                                                                             | <b>T10: Keynote &amp; Plenary II</b> <table><tr><td><b>Jeremy Schmit</b></td><td>Kansas State University</td></tr><tr><td colspan="2">Complexity Reduction and Concept Discovery: Lessons from Thermodynamics</td></tr><tr><td><b>Yasar Demirel</b></td><td>University of Nebraska Lincoln</td></tr><tr><td colspan="2">Biological Thermodynamics</td></tr></table>                                                                                                                                                                                                                                                                                  | <b>Jeremy Schmit</b>     | Kansas State University                       | Complexity Reduction and Concept Discovery: Lessons from Thermodynamics     |  | <b>Yasar Demirel</b>      | University of Nebraska Lincoln                     | Biological Thermodynamics                                            |  |                          |                                                 |                                                                                  |  |
| <b>Jeremy Schmit</b>                                                             | Kansas State University                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| Complexity Reduction and Concept Discovery: Lessons from Thermodynamics          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>Yasar Demirel</b>                                                             | University of Nebraska Lincoln                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| Biological Thermodynamics                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| 10:45                                                                            | <b>T11: Entropy and BioThermodynamics</b> <table><tr><td><b>Shripad Mahulikar</b></td><td>University of the Basque Country (EHU), Spain</td></tr><tr><td colspan="2">Radiation-Entropy Generation by Leaf and Negentropy Build-up of Plant as DS</td></tr><tr><td><b>Pier Luigi Gentili</b></td><td>Università degli Studi di Perugia, Perugia, Italy.</td></tr><tr><td colspan="2">The Fuzzy Entropy of Biomolecules and its Role for Life</td></tr><tr><td><b>Gregory Yablonsky</b></td><td>Washington University in St Louis</td></tr><tr><td colspan="2">New Invariances for Phenomena of Conservatively Perturbed Equilibrium</td></tr></table> | <b>Shripad Mahulikar</b> | University of the Basque Country (EHU), Spain | Radiation-Entropy Generation by Leaf and Negentropy Build-up of Plant as DS |  | <b>Pier Luigi Gentili</b> | Università degli Studi di Perugia, Perugia, Italy. | The Fuzzy Entropy of Biomolecules and its Role for Life              |  | <b>Gregory Yablonsky</b> | Washington University in St Louis               | New Invariances for Phenomena of Conservatively Perturbed Equilibrium            |  |
| <b>Shripad Mahulikar</b>                                                         | University of the Basque Country (EHU), Spain                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| Radiation-Entropy Generation by Leaf and Negentropy Build-up of Plant as DS      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>Pier Luigi Gentili</b>                                                        | Università degli Studi di Perugia, Perugia, Italy.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| The Fuzzy Entropy of Biomolecules and its Role for Life                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>Gregory Yablonsky</b>                                                         | Washington University in St Louis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| New Invariances for Phenomena of Conservatively Perturbed Equilibrium            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| 12:15                                                                            | <b>T12: Thermodynamics of Evolution</b> <table><tr><td><b>Michael Parker</b></td><td>University of Essex, Colchester, UK</td></tr><tr><td colspan="2">Thermodynamic Time and Entropic Purpose</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Michael Parker</b>    | University of Essex, Colchester, UK           | Thermodynamic Time and Entropic Purpose                                     |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>Michael Parker</b>                                                            | University of Essex, Colchester, UK                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| Thermodynamic Time and Entropic Purpose                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| 13:00                                                                            | <b>T13: Statistical and Quantum Thermodynamics</b> <table><tr><td><b>Tamas Matolcsi</b></td><td>Eötvös Loránd University (ELTE)</td></tr><tr><td colspan="2">Microscopic Irreversibility</td></tr><tr><td><b>Lock Yue Chew</b></td><td>Nanyang Technological University</td></tr><tr><td colspan="2">Quantum Thermodynamics of Refrigeration from Indefinite Causal Order</td></tr><tr><td><b>Peter Ván</b></td><td>Budapest University of Technology and Economics</td></tr><tr><td colspan="2">About the Dissipative Newton Equation</td></tr></table>                                                                                             | <b>Tamas Matolcsi</b>    | Eötvös Loránd University (ELTE)               | Microscopic Irreversibility                                                 |  | <b>Lock Yue Chew</b>      | Nanyang Technological University                   | Quantum Thermodynamics of Refrigeration from Indefinite Causal Order |  | <b>Peter Ván</b>         | Budapest University of Technology and Economics | About the Dissipative Newton Equation                                            |  |
| <b>Tamas Matolcsi</b>                                                            | Eötvös Loránd University (ELTE)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| Microscopic Irreversibility                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>Lock Yue Chew</b>                                                             | Nanyang Technological University                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| Quantum Thermodynamics of Refrigeration from Indefinite Causal Order             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>Peter Ván</b>                                                                 | Budapest University of Technology and Economics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| About the Dissipative Newton Equation                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| 14:30                                                                            | <b>T14: Constructal Law Application</b> <table><tr><td><b>Christine Bizzell</b></td><td>Canon Collaborative, Tulsa, OK, USA</td></tr><tr><td colspan="2">The Flow Architecture of Human Creativity: A Constructal Law Perspective</td></tr></table>                                                                                                                                                                                                                                                                                                                                                                                                  | <b>Christine Bizzell</b> | Canon Collaborative, Tulsa, OK, USA           | The Flow Architecture of Human Creativity: A Constructal Law Perspective    |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>Christine Bizzell</b>                                                         | Canon Collaborative, Tulsa, OK, USA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| The Flow Architecture of Human Creativity: A Constructal Law Perspective         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| 15:15                                                                            | <b>T15: Statistical Mechanics Applications</b> <table><tr><td><b>Victor Yakovenko</b></td><td>University of Maryland</td></tr><tr><td colspan="2">The Imminent Peaks of World Population and CO2 Emissions</td></tr><tr><td><b>David LACOSTE</b></td><td>David LACOSTE</td></tr><tr><td colspan="2">Debt, Growth and the Carbon Lock-in</td></tr><tr><td><b>Michael te Vrugt</b></td><td>Johannes Gutenberg University Mainz</td></tr><tr><td colspan="2">Effects of Social Distancing and Isolation on Epidemic Spreading Modeled via DFT</td></tr></table>                                                                                         | <b>Victor Yakovenko</b>  | University of Maryland                        | The Imminent Peaks of World Population and CO2 Emissions                    |  | <b>David LACOSTE</b>      | David LACOSTE                                      | Debt, Growth and the Carbon Lock-in                                  |  | <b>Michael te Vrugt</b>  | Johannes Gutenberg University Mainz             | Effects of Social Distancing and Isolation on Epidemic Spreading Modeled via DFT |  |
| <b>Victor Yakovenko</b>                                                          | University of Maryland                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| The Imminent Peaks of World Population and CO2 Emissions                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>David LACOSTE</b>                                                             | David LACOSTE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| Debt, Growth and the Carbon Lock-in                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| <b>Michael te Vrugt</b>                                                          | Johannes Gutenberg University Mainz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |
| Effects of Social Distancing and Isolation on Epidemic Spreading Modeled via DFT |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                          |                                               |                                                                             |  |                           |                                                    |                                                                      |  |                          |                                                 |                                                                                  |  |

# Day 2 PROGRAM

Thursday 6 August, 2026



16:30

T16: Thermodynamics and Economics

**Peter Corning**

Institute for the Study of Complex Systems, Seattle, WA.

Thermoeconomics: An Alternative Paradigm for Living Systems

**Albert Magnell**

University of Oxford, Oxford, UK

The Monetary Macroeconomics of Cellular Metabolism

**Burin Gumjudpai**

Mahidol University, Nakhonsawan Campus, Thailand

Effect Structure of Equations of State: Application to Demand-Side Economics

17:30

T17: Mickey Maini: Instruments for Measuring Stored Stress in Financial Systems

18:15

IAISAE General Meeting Thermodynamics 2.0 | 2026

End of Day 2 | T2026 Conference

# Day 3 PROGRAM

Friday 7 August, 2026



8:45

Registration and Networking

9:00

T18: Keynote & Plenary III

**Terry Bristol**

Portland State University, ISEPP

History of the Concept of Energy

**Umberto Lucia | Giulia Grisolia**

Politecnico di Torino, Corso Duca degli Abruzzi, Italy

Bioengineering Thermodynamics: Cellular Systems and Cancer Analysis

10:45

T19: Interdisciplinary Applications

**Yasuko Kawahata**

Rikkyo University, Japan

Reliability and Energy Dissipation Mapping of Tunnel Infrastructure: A Stochastic Mo..

**Marek Frankowicz**

Jagiellonian University in Krakow, Poland

Maintaining Order Far from Equilibrium: in Higher Education Systems

**Klaus Jaffe**

Universidad Simon Bolivar, Caracas, Venezuela

Infodynamics and Thermodynamics in Living System

11:45

T20: Exergy Applications

**Yazdan Pedramrazi**

San Jose State University, California

Exergy Analysis of an isothermal horizontal cylinder between shrouded plates

**Eduardo González-Mora**

Universidad Autónoma del Estado de México

Exergy Destruction in Concentrating Solar Collectors

12:30

T21: Charles Hall & Timothy McWhirter: The Evolution of Power and Entropy Production

13:15

IAISAE Honors Awards

End of T2026 Conference

# BOOK OF ABSTRACTS

Thermodynamics 2.0 | 2026



## Foreword

Thermodynamics is the science of heat, energy, and power. Alongside many other disciplines of science, technology, engineering, mathematics, and medicine (STEMM), thermodynamics has embodied a silent parallel evolution since its inception in the early 19th century. The foundational work of Sadi Carnot (1824) marked the genesis of this universal science by introducing the concept of the Carnot cycle and the associated science and technologies that power human society.

Many disciplines study different aspects of life and society. Their scale and resolution span from the basic unit of life—the biological cell—to the society of cells we witness in tissues, organs, organisms, and populations, all the way up to ecosystems and beyond. The methods of studying life range from faith-based religions and consciousness-based spirituality to GDP-based economics and measurement-focused sciences. As products of history and culture, these disparate areas of inquiry illuminate different facets of life, utilizing distinct terminology, theories, and methods. Nevertheless, the laws of thermodynamics apply to all of them.

As human knowledge advances, it is not unnatural to assume that the various disciplines studying energy, matter, and life will converge on the horizon. Emmy Noether's theorem, which links the conservation of energy to time-translation symmetry in nature, is the foundation on which modern science is built, evolving over three centuries from the classical, continuum to quantum levels. Does life conform to the science of energy? Many innovative thinkers hypothesize life as a manifestation of energy awaiting recognition. We don't know it for sure. Nonetheless, if the unity of science is a key to this horizon, a science of life must, in an appropriate limit, be consistent with the fundamental laws of matter such as those formulated by Newton, Maxwell, and others. This is sometimes interpreted in the literature as Bohr's correspondence principle.

"It is important to realize that in physics today, we have no knowledge what energy is." Feynman was right about the current state of human knowledge regarding energy, and a similar statement could be made about the science of life. The Thermodynamics 2.0 framework integrates the study of energy, life, and matter in a way that aspires to bridge the natural and social sciences.

A first step toward a novel science of life is to characterize the fundamental unit of life, the biological cell, by synthesizing the knowledge embedded in the troves of data experimentalists have accumulated across various levels of biological organization. Light and Life (Neils Bohr, 1933) is a promising framework to integrate physics, biology, and many others disparate sciences to come up with a science of life. Indeed as Bohr observed then: in actual atomic phenomena we meet with features which show a closer resemblance to the properties of living organisms. Some physicists are inching the opportunity to reconcile Bohr's insights to explain the levels of biological organization for it could be that we have no knowledge of what energy is, nonetheless, many engineers have embraced his wisdom to elucidate the properties of living organisms by entrusting the dynamic similarities we observe in natural phenomenon of heat transfer and its engineering applications. We need to develop a "sociology of cells" by extending the many-body system framework honed in physics and engineering. This approach demands bridging disparate sciences that currently focus on a single scale and remain siloed in academic departments across the natural and social sciences. Thermodynamics connects various levels of organization (micro-, meso-, and macro-) and description through the shared language of energy and its derivatives. This is why thermodynamics plays a unique role in the science of life, potentially helping settle the changing narratives of biology by providing a robust Lyapunov form and function. The next step will involve building consensus and mapping distinct terminologies across thermodynamics and the disparate sciences of life. Equally probable that life may never fully yield to science; the measurement problem associated with an observer and the subjective nature of life present formidable challenge to human knowledge of natural phenomenon of life.

Thermodynamics 2.0 conference presents a confluence of such efforts across the natural and social sciences. This dynamic discipline continues to inspire both new generations of researchers and accomplished professors across traditional fields as it is reflected in the T2026 contributors list.

This year, we lost one of the seasoned contributors to Thermodynamics 2.0, **Miroslav Grmela (1939–2026)**. Miroslav was a concluding speaker at the T2020 conference, and at the T2024, he provided the keynote address. I have no doubt his contributions to rate thermodynamics and multiscale thermodynamics will continue to endure among us, offering a guidance toward the unity of the sciences. A deeper understanding of the science and technology of life might emerge by integrating reversibility and irreversibility, as Miroslav was embracing all along, within the field-based framework of science.

Energy transfer is a primary driver of all natural phenomena including the fundamental unit of life, the biological cell, and its society. Thermodynamics is indeed a universal science, and all dynamics of science are thermodynamics!

## THE IMMINENT PEAKS OF WORLD POPULATION AND CO<sub>2</sub> EMISSIONS

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### ABSTRACT

In the *Science* paper [1] published in 1960, Heinz von Foerster et al. argued that human population growth is hyperbolic  $N(t)=C/(t_s-t)$  with a singularity in the year  $t_s=2026$ . Using current empirical data from 10,000 BCE to 2023 CE, we re-examine this claim [2]. We find that world population initially grew exponentially in time as  $N(t)\sim\exp(t/T)$  with  $T\sim 3000$  years. This growth then gradually evolved to be super-exponential with a form similar to the Bose function in statistical physics. Population growth further accelerated around 1700, entering the hyperbolic regime with the extrapolated singularity at  $t_s=2030$ , which essentially confirms the claim of Ref. [1]. We attribute the onset of the hyperbolic regime to the transition to massive use of fossil fuels upon the Industrial Revolution, as evidenced by a linear relation that we find between world population and the increase in CO<sub>2</sub> level from 1700 to 2000. But in the 21st century, the inverse population curve  $1/N(t)$  deviates from a straight line and follows a pattern of "avoided crossing". As a result, the singularity transforms into a square-root Lorentzian peak at  $t_s=2030$  of the width  $\tau=32$  years. Our predicted year 2030 of the peak in world population is much earlier than in other demographic forecasts. We also find that the increase in the CO<sub>2</sub> level since 1700 is well fitted by  $\text{arccot}[(t_s-t)/\tau_F]$  with  $\tau_F=40$  years. Thus, we forecast a Lorentzian peak in the annual emissions  $d(\text{CO}_2)/dt$  at the same year  $t_s=2030$ .

**Keywords:** world population peak, hyperbolic singularity, CO<sub>2</sub> emissions, fossil fuels, Industrial Revolution

### References:

- [1] H. von Foerster et al., "Doomsday: Friday, 13 November, A.D. 2026", *Science* **132**, 1291 (1960)  
<https://doi.org/10.1126/science.132.3436.1291>
- [2] V. M. Yakovenko, "The end of hyperbolic growth in human population and CO<sub>2</sub> emissions", *Physica A* **661**, 130412 (2025),  
<https://doi.org/10.1016/j.physa.2025.130412>
- [3] Link to additional materials: <https://physics.umd.edu/~yakovenk/population/>

**RELIABILITY AND ENERGY DISSIPATION MAPPING OF TUNNEL INFRASTRUCTURE: A  
STOCHASTIC MODEL FRAMEWORK VALIDATED VIA EXTENSIVE MONTE CARLO  
ENSEMBLE ANALYSIS**

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**ABSTRACT**

Much of Japan's social infrastructure was concentrated during the period of rapid economic growth around the 1970s and is now facing the serious problem of simultaneous aging. To address this, a shift from conventional reactive maintenance to asset management utilizing various data is urgently needed. However, a critical barrier in practice is that inspection data predominately exists in analog paper formats or unstructured files, relying on subjective expert ratings (e.g., scale A to D). This lack of digital structure and the presence of "Assessor Bias" make it difficult to secure the robustness required for direct statistical analysis. To advance data analysis under these constraints, it is crucial to first verify whether a mathematical model can handle such uncertainty. This paper focuses on verifying the robustness and convergence of a deterioration prediction model designed to bridge this gap. Specifically, it incorporates the expert's "judgment variation" into the model as probabilistic fluctuations (e.g., Beta-distributed noise) and uses large-scale Monte Carlo simulations to verify whether the model can produce stable results. This establishes a foundation for advancing future data analysis. Based on these verifications, we promote not only the "micro-segmentation of homogeneous statistical populations" but also the "micro-detailing of analytical models." Such efforts are expected to drive the shift from qualitative methods reliant on human intuition to quantitative methods in modern society.

Keywords: evolution, cooperation, society, social field theory, energetics



## INFODYNAMICS AND THERMODYNAMICS IN LIVING SYSTEMS

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### ABSTRACT

For infodynamics, consciousness is the mechanism whereby models of the surrounding world (mental or otherwise), constructed by an individual, include the self. If this model also includes parts of the consciousness of others, empathy emerges. This definition contradicts Illusionism who claim that subjective consciousness is a useless byproduct or a trick. For Infodynamics it has a concrete, measurable biological and thermodynamic purpose: adaptation. It also contradicts Panpsychism who believe consciousness is a fundamental property of all matter (even rocks). For Infodynamics consciousness requires an advanced system capable of storing, retrieving, and actively evaluating information. It also contradicts Phenomenalism that focuses on what it *feels* like to see a color for example. Infodynamics focuses entirely on what the organism does with this information to optimize its survival. The Infodynamic definition allows to detect consciousness in other living creatures and serves to design advanced artificial intelligence. Feelings related to consciousness are based on adaptive instincts that motor our actions and mold our behavior.

Keywords: Infodynamics, consciousness, purpose, adaptation

## EXERGY DESTRUCTION IN CONCENTRATING SOLAR COLLECTORS

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### ABSTRACT

Solar-to-energy conversion for electricity and industrial process heat relies on two competing routes. Photovoltaic conversion is the more widely deployed technology for power generation, yet its exergy efficiency remains low relative to conventional thermal plants. Photothermal conversion, by contrast, concentrates solar irradiance ahead of its use in a power cycle or a process-heat application; this route — known as concentrating solar power (CSP) when applied to electricity generation — has been shown to reach exergy efficiencies comparable to conventional plants. A question of practical relevance to the optimisation and selection of collector technology nonetheless remains insufficiently addressed: how much exergy is destroyed within the collector itself, independently of the downstream cycle or process?

This work quantifies that irreversibility using the authors' MPD model (Mora, Poudel, Durán) for the exergy content of solar irradiance, combined with a general exergy balance applied across the collector. The concentrating device is characterised through the concentration–acceptance product, together with the absorber and ambient temperatures and the conductance governing heat losses to the surroundings. The balance is applied to six representative technologies spanning the non-concentrating and concentrating ranges: flat-plate collectors, compound parabolic concentrators (CPC), parabolic trough collectors (PTC), linear Fresnel reflectors (LFR), solar towers, and parabolic dishes (PD). The results show that, for each technology, exergy destruction reaches a minimum at a specific absorber temperature and increases as the absorber departs from this optimum in either direction. These findings constitute a first step towards a comprehensive advanced exergy analysis of solar collectors — resolving destruction into its endogenous/exogenous and avoidable/unavoidable components — to guide future optimisation of CSP and solar process-heat systems.

Keywords: exergy, solar irradiance exergy, concentration–acceptance product, concentrating solar collectors

## EXERGY ANALYSIS OF AN ISOTHERMAL HORIZONTAL CYLINDER BETWEEN SHROUDED PLATES

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### ABSTRACT

In this paper, we study the horizontal isothermal cylinder between vertically insulated plates. This problem from a heat transfer point of view was analyzed [1]. Though it is not stated directly, it treats the problem from constructal point of view. Here in this paper, an exergetic analysis of the problem is undertaken. Our analysis begins with efficiency; then it is modified to account for the exergy analysis. It should be mentioned that this problem has not been treated before because the heat transfer aspects of it were not treated before.

Keywords: exergy, constructal law, heat transfer, exergy analysis

### References:

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## **THERMOECONOMICS: AN ALTERNATIVE PARADIGM FOR LIVING SYSTEMS**

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### **ABSTRACT**

Physicist Ervin Schrödinger's landmark book, *What is Life?* (1945), has inspired many subsequent efforts to understand and explain biological evolution, especially the evolution of complex systems, in terms of the Second Law of Thermodynamics and the concepts of "entropy" and "negative entropy." In contrast, thermoeconomics is based on the premise that the role of energy in biological evolution is best defined and understood, not in terms of the Second Law but in terms of the economics -- the costs and benefits (or "profitability", net of entropy) of the activities associated with capturing and utilizing available energy to build biomass and do work. Furthermore, thermoeconomics criteria provide a better predictor of the advances and recessions in biological complexity than does any formulation derived from the Second Law.

Keywords: thermodynamics, economics, entropy, information, synergy



## ENERGY AND EVOLUTION: THE SYSTEMS APPROACH

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### ABSTRACT

In the wake of Boltzmann's landmark work, a thermodynamic school of evolutionary theory has emerged, offering a multitude of principles alleged to guide evolutionary development. Many scientists have championed their principle of choice, arguing that their perspective is more "accurate" or "general" than competing theories. In several cases, reliance on straw man arguments has undermined our ability to understand the precise relations among these principles.

In the 1990s, a group of scientists led by Sven Jørgensen began to explore how these optimality principles work together to form a cohesive pattern, which Jørgensen describes using his proposed fourth law of thermodynamics. A similar approach had been suggested by H. T. Odum using his maximum power principle, though he never fully developed it, and it was largely overlooked. This presentation summarizes a book project that critically examines the relationship between these two approaches. We demonstrate that Jørgensen and his colleagues did not accurately define Odum's maximum power principle. As a result, they failed to recognize its unique relation to the principle of natural selection, its fundamental role in the causal hierarchy of evolutionary development, and its capacity to describe more accurately the complex ways optimality principles interact in evolutionary processes.

**Keywords:** evolution, thermodynamics, energetics, the maximum power principle (MPP)



## THE EVOLUTION OF POWER AND ENTROPY PRODUCTION

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### ABSTRACT

In the 20<sup>th</sup> century, a thermodynamic school of evolutionary theory emerged, offering a number of principles alleged to guide evolutionary development. These include the maximum power principle (MPP) and the maximum entropy production principle (MEPP), along with a long list of other “optimality” principles. The MPP and the MEPP are the products of two different “divisions” of thermodynamic school of evolutionary theory: those who developed the MPP were influenced by Darwin, Boltzmann, and the principle of natural selection; those who developed the MEPP were influenced by Carnot, Clausius, and the second law of thermodynamics.

We are working on a book project that explores the thesis that the evolutionary process is a complex system with many different parts that are connected by a web of relations. We argue the different optimality principles focus on different parts of this process, and we aim to explain the relations among these principles. In this presentation, we focus specifically on the relation between the MPP and the MEPP. We demonstrate that while both of these approaches describe accurately evolutionary development, they have fundamentally different relations to the principle of natural selection: the output of useful power is selected directly in evolutionary processes; the production of entropy is selected necessarily, but indirectly, because it is fundamentally related to the output of power. Ultimately, clarifying the relations between these two principles, and the other optimality principles, provides a more accurate and comprehensive understanding of evolutionary development.

**Keywords:** evolution, thermodynamics, energetics, the maximum power principle (MPP), the maximum entropy production principle (MEPP)

## DEBT, GROWTH AND THE CARBON LOCK-IN

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### ABSTRACT

Despite decades of climate policy and rapid improvements in energy efficiency, global CO<sub>2</sub> emissions continue to rise, suggesting the presence of structural drivers that offset efficiency gains. Here we identify financial leverage as a key mechanism underpinning this persistent overshoot.

We develop a stochastic macro-financial model linking credit dynamics, economic growth, bankruptcy risk, and cumulative carbon emissions. The model shows that debt-financed growth systematically amplifies cumulative emissions, locking economies into high-carbon trajectories even as emissions intensity declines.

This arises from a double constraint: debt repayment requires sustained growth, while growth remains energy-dependent and thus generates emissions. When growth becomes increasingly dependent on leverage, financial instability and cumulative emissions rise, while gains in real wealth diminish, revealing a leverage frontier beyond which additional credit primarily generates risk.

Calibrating the model to multi-decade data for the United States, China, France and Denmark, we find a robust coupling between debt accumulation, cumulative GDP and cumulative emissions across distinct economic structures. These results challenge the feasibility of growth–emissions decoupling under prevailing credit-driven growth regimes and indicate that achieving net-zero targets requires aligning credit allocation with decarbonisation objectives.

Keywords: decarbonisation, carbon emissions, economic growth, debt, carbon lock-in

## RADIATION-ENTROPY GENERATION BY LEAF AND NEGENTROPY BUILD-UP OF PLANT AS DISSIPATIVE STRUCTURES

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### ABSTRACT

Photosynthesis has not been achieved artificially due to the difficulty in radiation entropy production by the high processing ability of PAR (photosynthetically active radiation) that is needed. Plant is a self-organising Dissipative Structure (DS); since, it's leaf generates radiation entropy in the surroundings, for the existence of plant with possible growth. Radiation entropy production in the surroundings is requirement for mandatory 2<sup>nd</sup> Law compliance; only then, the photochemical reaction leading to the formation of biomass can take place. Entropy density (entropy-energy ratio) of PAR that is processed and then emitted by the plant-leaf ( $s_{E,rel}$ ) exceeds that absorbed ( $s_{E,in}$ ), by a factor,  $\Pi_{E,leaf} = (s_{E,rel}/s_{E,in}) \sim 20$ . Entropic measure of the high processing level of PAR is,  $\Pi_{E,leaf} (>>1)$  - it determines the margin for plant-growth based on the photosynthetic efficiency in PAR,  $\eta_{ph,PAR} (>0, \text{ for plant-growth})$ . The  $\Pi_{E,leaf}$  is a stronger function of the leaf's temperature (higher at lower  $T_{leaf}$ ) relative to the wavelength within PAR processed (higher at lower  $\lambda$ ). Plants can build their negentropy ( $s_{neg}<0$ ) also by processing radiation (in addition to matter), by the difference,  $s_{neg,rad} = s_{E,rel} - s_{E,in} (<0)$ . The  $|s_{neg,rad}|$  has a much higher contribution to the plant's self-organization as DS with growth potential. In  $|s_{neg,rad}|$ , changes in  $s_{E,rel}$  and  $s_{E,in}$  are multiplied by a huge factor,  $c^2$ ; where,  $c$  is the speed of light. Hence, even a small rise in  $s_{E,rel}$  and a small drop in  $s_{E,in}$  can significantly increase  $|s_{neg,rad}|$ . It increases with decreasing  $T_{leaf}$  and is higher at lower wavelength (in PAR) processed. But only a part of this difference can be the source of free energy, stored as plant-growth. Remaining part of  $|s_{neg,rad}|$  is dissipated in the surroundings, which is the excess payment of negentropy debt as part of 2<sup>nd</sup> Law compliance. Thermodynamic performance of photosynthesis depends on the processing level of PAR,  $\Pi_{E,leaf} = (s_{E,rel}/s_{E,in})$ ,  $|s_{neg,rad}|$ , and is limited by the maximum photosynthetic efficiency in PAR,  $\eta_{ph,PAR,max}$  (it increases with  $\Pi_{E,leaf}$ ). The  $\eta_{ph,PAR,max}$  is obtained in terms of  $T_{leaf}$  and the spectral temperature of the Sun,  $T_{sun\lambda} [= (1/s_{E,in})]$ . Expression for  $\eta_{ph,PAR,max}$  correlates with that for the maximum thermodynamic efficiency of reversible Carnot engine,  $\eta_{cycle,max}$ . For both cases,  $\eta_{ph,PAR,max}$  and  $\eta_{cycle,max}$ , no net entropy is generated in the surroundings.

Keywords: biomass; dissipative structure; entropy; negentropy; photosynthesis



## THERMODYNAMIC TIME AND ENTROPIC PURPOSE

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### ABSTRACT

The Principle of Least Entropic Purpose was established by Parker *et al.* (*Entropy* **27**, 2025, 131) as the line integral of the entropic “purposive” Lagrangian defined in complex time. As a physico-mathematical object, the purposive Lagrangian is purely temporal (with no spatial component) and obeys the appropriate Euler-Lagrange equations across the complex time plane. The variational description in thermodynamic (hyperbolic) time is based on the Quantitative Geometrical Thermodynamics formalism, that describes the trajectory traversed across the complex temporal plane by a system as it exhibits its Entropic Purpose (measured by the Shannon Information created in the process). Trajectories in complex time may not cross (since this creates never-ending repetitive loops contra the Second Law of Thermodynamics). The imaginary time-axis is associated with reversible (adiabatic) thermodynamic processes, whereas irreversibilities and dissipative (entropy increasing) processes are associated with real time. The length of any trajectory across the complex time plane represents the empirical (measured) scalar time of the process and is calculated by summing the real and imaginary temporal components in quadrature (as usual). The fractal time scale (logarithmic half-life) determines the length of a temporal trajectory and also the associated information production. A purposive system’s energy Hamiltonian (in general, complex) also yields its information production: In the trivial reversible case, the information production is zero for a purely real Hamiltonian and is associated with double-helical (circular) geometries in complex time, while dissipative processes are marked by double logarithmic spirals. The Mandelbrot set located across the complex time plane is the mathematical structure *par excellence* that manifests the highly informational properties of Thermodynamic Time and Entropic Purpose. All fractal temporal scales and purposive trajectories are simultaneously present in the Mandelbrot set, with each location in the set representing an informational, discrete point of non-analyticity. Double logarithmic spirals (DLSs) are clearly present, representing Lagrangian trajectories that are information-producing and therefore purposive.

Keywords: entropy, complex time, purpose, Shannon information, purposive Lagrangian, Euler-Lagrange, complex Hamiltonian, entropy production

## ABOUT THE DISSIPATIVE NEWTON EQUATION

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### ABSTRACT

The fundamental nature of the second law of thermodynamics can best be examined through its contribution to fundamental theories and through experiments. Numerous examples demonstrate how thermodynamic concepts contribute to the foundations of physics [1–2]. In such cases, compatibility with existing approaches is the main goal, but experimental verifications and predictions that differ from existing approaches are rare.

In this presentation, I show the thermodynamic foundations of classical mechanics. Within this framework, ideal Newtonian mechanics appears as the dissipative-free limit of a more general, dissipative theory. The thermodynamic approach predicts a simple but novel, dissipative contribution to momentum that depends on the applied force and leads to a damping coefficient whose dependence on the inertial mass is specific and experimentally verifiable. Several well-known equations, including the thermodynamic version of the Eliezer–Ford–O’Connell equation for radiation reaction, can be derived as special cases. Furthermore, a torsion balance experiment with a variable moment of inertia has been designed to measure this effect. The first results of these measurements are shown.

Keywords: Newton, classical mechanics, thermodynamics, dissipative theory

### References:

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**THE FLOW ARCHITECTURE OF HUMAN CREATIVITY: A CONSTRUCTAL LAW  
PERSPECTIVE**

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**ABSTRACT**

Human creativity has long been studied as a psychological phenomenon. This paper proposes a complementary physical framing, governed by the same dynamics that shape rivers, lungs, and vascular networks. Drawing on the Constructal Law and complementary systems science, it argues that creative capacity emerges when the channels through which perception, attention, and meaning move are well-designed, and contract when they are not.

Constructal Law states that for a finite-size flow system to persist in time, it must evolve with freedom to provide easier and greater access to what flows through it. This paper applies that principle to human creativity, proposing that each individual carries an internal flow architecture — embodied, tacit structures through which creative energy moves most naturally into the external niche environment.

When work and career align with that unique individual architecture, creativity tends to emerge and renew itself. When they do not, resistance accumulates and may lead to burnout. In this frame, burnout is not a personal failure but a structural signal: evidence that flow has been chronically constrained. This reframe carries direct implications for how organizations design work, how individuals understand their own creative limits, and how we might design systems that release human creativity rather than exhaust it.

Keywords: Constructal Law, living systems, human creativity, flow architecture, burnout



**QUANTUM THERMODYNAMICS OF REFRIGERATION FROM INDEFINITE CAUSAL ORDER**

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Quantum Thermodynamics of Refrigeration from Indefinite Causal Order

**ABSTRACT**

Indefinite causal order has been shown to enable nonclassical refrigeration. Recent experiments have further demonstrated that an ensemble of nuclear spins in the nuclear magnetic resonance system can boost the prior coefficient of performance (COP) through the approach of density matrix exponentiation (DME). In this talk, we elucidate a technique to improve the COP of this setup by incorporating an information pool of qubits to absorb the entropic cost of refrigeration. We found that if these qubits are reused until their resources are expended, an increase of the COP beyond the DME approach can be achieved in certain temperature ranges. This improvement is observed to hold even for the case when the working body is hotter than the cold bath, with further enhancements obtained in the pre-thermalization regimes. Our work thus illustrates how indefinite causal order can be fruitfully applied to the quantum thermodynamics of refrigeration.

Keywords: quantum thermodynamics, quantum refrigeration, indefinite causal order

## **HISTORY OF THE CONCEPT OF ENERGY**

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### **ABSTRACT**

In considering the history of the concept of energy, one would presume to have a clear and distinct concept of nature of energy. CS Peirce argued that abstract scientific or mathematical concepts are inherently confused, ambiguous and ultimately undecidable. Clear and meaningful concepts are decidable by observation of their experimentally demonstrable consequences. Clearly any history of the concept of energy must be clarify the conceptual framework within which the question of the nature of energy itself is being formulated.

There are two competing frameworks: one defined by the presuppositions of classical mechanics, the other defined by the presuppositions of engineering practice. I will argue that an understanding of the history of the concept of energy is inseparable from an understanding of the history of thermodynamics.

Section One begins with Atkins pointing out that we are offered two histories of thermodynamics. The Clausius, Boltzmann, Gibbs history is based in classical mechanics. The Carnot history arose from the new understanding of heat engines. Atkins emphasizes that there are two corresponding modern formulations, classical mechanical thermodynamics and engineering thermodynamics. Section Two explores the contrasting perspectives on thermodynamics more broadly in terms of the Analytic and Synthetic traditions. Section Three develops Lazare Carnot's dynamic engineering worldview.

Just as classical mechanics can't make sense of engineering practice, there is no engineering practice and there are no engineers in the classical mechanical worldview. Carnot's engineering worldview moves to a participant engineering perspective wherein the capacity to perform work is internal to the agent, not attributable to an external 'force' or 'cause'. Carnot's Epiphany is that we are engineers in a world of engineering, agents in a world of agency 'Energy' in Carnot's engineering worldview is to be understood qualitatively, teleologically, as the capacity to manifest value.

**Keywords:** History, thermodynamics, concept, energy, engineering worldview

**EFFECTS OF SOCIAL DISTANCING AND ISOLATION ON EPIDEMIC SPREADING  
MODELED VIA DYNAMICAL DENSITY FUNCTIONAL THEORY**

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**ABSTRACT**

For preventing the spread of epidemics such as the coronavirus disease COVID-19, social distancing and the isolation of infected persons are crucial. However, existing reaction-diffusion equations for epidemic spreading are incapable of describing these effects. Here, we present an extended model for disease spread based on combining a susceptible-infected-recovered model with a dynamical density functional theory where social distancing and isolation of infected persons are explicitly taken into account. We show that the model exhibits interesting transient phase separation associated with a reduction of the number of infections, and allows for new insights into the control of pandemics.

## MICROSCOPIC IRREVERSIBILITY

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### ABSTRACT

The contradiction of micro-reversibility and macro-irreversibility is an old problem in statistical mechanics. The article clarifies the conceptual differences of the various formulations of this contradiction and then it argues as follows.

1. It states that
  - probabilities, arising from our lack of knowledge, cannot explain irreversibility, which is a physical fact, independent of us,
  - irreversibility which is a physical fact, independent of us, can explain probabilities arising from our lack of knowledge.
2. It points out that the concept of micro-reversibility arises from the non-relativistic Hamiltonian equation of interacting particles, which is time-reversal invariant, but relativity theory revealed that there is no interaction at a distance between particles, so instead of mechanical particle-particle interaction, particle-field interaction should be taken when treating microscopic phenomena in statistical physics.
3. It examines different attempts to describe the particle-field interaction and finds that a well-working description does not exist at present.
4. It states that there is an asymmetry in processes of emission and absorption: a particle emits radiation depending on its states but radiation for absorption arrives at it independently of its states.
5. It supposes that irreversibility can be the consequence of particle-field interaction, more closely irreversibility can be based on the asymmetry of emission and absorption.  
If this is true then irreversibility is present also at the microscopic level, and the contradiction of microscopic reversibility and macroscopic irreversibility disappears.
6. The final resolution of the contradiction would only be possible if there were an accurate description of particle-field interaction.

The irreversibility is present even at the microscopic level because of the particle-field interaction, hence, there may actually be no contradiction.

Keywords: micro-reversibility, macro-irreversibility, particle-field interaction, statistical mechanics



## THERMODYNAMIC CONSTRAINTS AS PHYSICAL BIAS IN DEEP LEARNING FOR PROTEIN DESIGN

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### ABSTRACT

Deep learning has accelerated protein design, yet current methods often neglect the thermodynamic principles that govern protein stability and function. We present a framework for incorporating thermodynamic constraints as physical biases within deep learning workflows, enabling the design of proteins with predictable behavior across varying temperature and solvent conditions.

We demonstrate this approach through three case studies spanning distinct protein engineering challenges. For the reporter protein NanoLuc, we combine expert-guided deep learning with thermodynamic filtering to enhance luciferase activity and stability beyond what directed evolution or rational design alone achieve. For the lipase LipA, we show how physics-driven filters resolve ambiguities in deep learning predictions for industrial substrate hydrolysis at non-ambient conditions. For MapKinase, we apply conformation-specific design principles to engineer constitutive activity, requiring accurate modeling of the free energy landscape between active and inactive states.

Across these systems, we find that embedding thermodynamic reasoning—particularly temperature-dependent stability predictions and conformational free energy differences—improves the success rate of designed variants. We discuss how thermodynamic biases can guide deep learning toward physically realistic predictions at conditions not well-represented in training data, and outline validation strategies using experimental activity and stability measurements.

Keywords: protein design, deep learning, thermodynamics, physical bias, conformational stability, enzyme engineering



## CHARACTERIZATION OF PARTICLE TRAJECTORIES DURING DIELECTROPHORESIS COLLECTION AND THE PHYSICAL PHENOMENA OF INSULATOR COVERAGE OVER THE ELECTRODES

Ramona Luna, Stuart Ibsen

### ABSTRACT

It is known that tumors shed various nanoparticles into circulation even at the early stages. Due to their small size and low abundance, it is challenging to recover and detect these particles from plasma, especially at early cancer stages where biomarker levels are low. Early cancer detection is critical to improve treatment outcomes. High conductance dielectrophoresis (DEP) is a promising technology to recover these particles based on their dielectric differences with the surrounding plasma. Better understanding the interaction between the particles and the electric field will aid in designing new methods to improve collection of rare cancer derived particles and increase device sensitivity when biomarker abundance is low in early-stage cancer samples.

Consequently, we studied the behavior of particles and physical phenomena that occur inside these microarray chips when DEP is applied. The chips were purchased from Biological Dynamics and have a unique hydrogel layer to protect the sample and electrodes from electrochemical destruction. It has been observed that when DEP is applied, the hydrogel partially detaches from the electrode surface forming domes. When domes are present, the collection of particles is enhanced at the edges of the circular electrodes. We used COMSOL Multiphysics Software to model the effect of the dome on the electric field, and various insulating materials that could be within the dome. Our results suggest that DEP high field regions intensify and localize at the edges of the electrodes when domes are formed leading to enhanced collection of particles. Moreover, we analyzed the trajectories of individual particles under the influence of negative DEP as they moved towards collection in low regions of the electric field to understand how well the theoretical field gradients matched particle motion.

The analysis of the relationship between the enhanced collection and the dome formation in addition to the study of particle trajectories, enable future optimization of protocol development to enhance collection when there is low abundance of biomarkers. Further studies will involve particle tracking experiments for different sizes of particles and analyzing how the formed domes affect the particle trajectories in DEP collection experiments.

Keywords: dielectrophoresis, negative dielectrophoresis, cancer early detection, particle isolation.

## NEW INVARIANCES FOR PHENOMENA OF CONSERVATIVELY PERTURBED EQUILIBRIUM

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### ABSTRACT

In chemical kinetics, the phenomenon of “Conservatively Perturbed Equilibrium” (CPE) has been previously distinguished and analyzed since its discovery in 2019. In this paper, the new invariances, so called ‘master curves’, for linear mechanisms with degrees of freedom of one have been found and studied. Gibbs Free Energy ( $G$ ) has also been extensively analyzed with consideration to CPE, involving energy levels and trajectories.  $G$  and  $dG/dt$  are expressed as follows:

$$G = RT \sum_i c_i [\ln(c_i/c_{i,eq} - 1)] \quad (1)$$

$$dG/dt = -RT \sum_i r_s [\ln(r_s^+/r_s^-)] \quad (2)$$

where  $r_s = r_s^+ - r_s^-$  is the reaction rate of the  $s$ -th step,  $c_i$  and  $c_{i,eq}$  are  $i$ -th concentration and  $i$ -th equilibrium concentration, respectively.

For general  $n$ , we find: 1) time(s) of CPE-points do not depend on the magnitude of perturbations, 2) for the unperturbed substance, the deviation of the CPE-extremum value from the initial equilibrium concentration is proportional to the value of perturbation of the perturbed concentration, i.e. its initial deviation, and 3) for the unperturbed substance, the individual contribution to the  $G$  will experience extremum, and its derivative will experience inflection point(s), both occurring at these CPE time(s).

For  $n = 3$ , it was found that the times of all CPE points across substances are equal. This is not held for general  $n$ . These obtained properties can be used both for revealing the chemical mechanism structure and for industrial applications, e.g., the obtaining of the over-equilibria which have been found and studied computationally in industrial methane reforming reactions.

Keywords: Conservatively Perturbed Equilibrium CPE, Chemical Kinetics, Extreme Value

**REGULATORY CONTROL, IRREVERSIBILITY, AND MAJOR EVOLUTIONARY  
TRANSITIONS IN LIVING SYSTEMS**

**Zuchang Pei**

**ABSTRACT**

Classical thermodynamics successfully explains energy dissipation and entropy production in physical systems, yet struggles to account for the sustained organization, directional complexity, and innovation observed in living and social systems. Here, we propose a bioevo-cybernetic extension of thermodynamics—Thermodynamics 2.0—that integrates energy flow with regulatory control and feedback-driven stability. Using a thermodynamic–regulatory formalism (the Selection–Regulation–Transition, SRT, model), we show that major evolutionary transitions arise not from selection alone, but from the co-evolution of selective pressures and internal regulatory architectures. When internal feedback networks exceed a critical stability threshold, systems enter new dynamical regimes characterized by coherent energy dissipation, enhanced robustness, and the emergence of higher-order organizational capacities. Numerical simulations demonstrate that purely selection-driven dynamics frequently yield unstable or collapsing trajectories, whereas coupling selection with regulatory feedback produces stable lineages, modular organization, and hierarchical control. These results provide a unified mechanistic explanation for empirical phenomena traditionally treated separately, including canalization, robustness, facilitated variation, and punctuated adaptive radiations. We interpret major evolutionary innovations—such as multicellularity, neural control, and symbolic cognition—as cybernetic phase transitions in which regulatory integration reorganizes thermodynamic constraints, enabling irreversible increases in adaptive complexity. By reframing evolution as a process of thermodynamic control rather than passive optimization, this framework offers a transferable conceptual bridge linking biology, complex adaptive systems, and social evolution, and contributes to an emerging Thermodynamics 2.0 centered on regulation, information, and directional change.

**Keywords:** Regulation, control, evolution, transition, living system



## THE FUZZY ENTROPY OF BIOMOLECULES AND ITS ROLE FOR LIFE

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### ABSTRACT

Life is an emergent property of cells, which are complex chemical systems constantly far from thermodynamic equilibrium [1]. Every living being is made of phospholipids, water, proteins, RNA, DNA, sugars, salts, and other compounds. Taken separately, these compounds never show the phenomenon of life. Life emerges only if all the necessary molecular constituents are organized into a peculiar hierarchical network structure, namely a cell [2]. The complexity of any cell primarily stems from molecular complexity [3]. Molecules can be described as atomic networks that can assume distinct three-dimensional architectures, called stereoisomers. Within a cell, proteins, DNA, and RNA typically exist as collections of many conformational stereoisomers (conformational ensembles), resulting in multispecificity and adaptability [4]. Any conformational distribution of a compound implements a molecular fuzzy set, which is also a quantum mixed state [4, 5]. The amount of information encoded by any conformational distribution is its fuzzy entropy ( $H$ ):

$$H = - \sum_{k=1}^{N_c} w_k \log(w_k) \quad (1)$$

In equation (1),  $N_c$  represents the number of conformers and  $w_k$  is the relative abundance of the  $k$ -th conformer. Different conformers of the same macromolecule exhibit distinct reactivity. The parallel reactivity of many conformers constitutes a form of quantum parallelism, expressing a molecular language that is inherently fuzzy. The theory presented in this contribution offers a challenging perspective on living cells, which is inspirational for Chemical AI [5, 6]. Chemical AI refers to all chemical systems in liquid solutions that, when maintained in out-of-equilibrium conditions, reproduce some competencies of biological intelligence [6].

Keywords: Life, Out-of-equilibrium Thermodynamics, Conformations, Fuzzy Entropy

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## STATISTICAL PHYSICS OF FINANCE

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### ABSTRACT

Statistically, financial data are not fundamentally different from economic data. Skewed distributions, sigmoid cumulative curves, power laws, oscillations, and chaotic courses are also ubiquitous in many other fields of study. Therefore, we reason that financial markets follow the same principle as other systems, the second law of thermodynamics, and theorize the management of money accordingly. We describe a financial system like any other system using statistical physics based on the atomistic axiom that everything comprises the same fundamental elements, known as quanta, viz, light quanta. This theory formalizes every system by the same general equation of state and every process by the same general equation of motion. In essence, statistical physics reveals that money flows along the lines of force, i.e., paths that minimize free energy in the least time. We show that this quest for thermodynamic balance results in ubiquitous patterns, i.e., fat-tailed distributions that sum up sigmoidally, hence mostly following power laws that characterize, for example, stock market volatility. Despite power laws, log-normal distributions, logistic curves, and other deterministic functions tracing data quite well, we infer that natural processes are inherently intractable because motions consume driving forces, e.g., investments affect future investments. Since variables cannot be separated, the path-dependent equation of motion cannot be solved. That is to say, the future cannot be predicted, but it is still bounded by free energy. Specifically, we argue that financing is not a truly random or indeterminate process, as assumed by many models, but a non-deterministic process driven by forces. In this way, non-equilibrium thermodynamics, derived from the statistical physics of open, quantized systems, makes sense of market dynamics, value assessment, and decision-making. The proposed perspective, which incorporates international finance as an integral part of the global economy embedded in planetary environments, also offers insight into a sustainable way of life. In this paper, we study the horizontal isothermal cylinder between vertically insulated plates. This problem from a heat transfer point of view was analyzed [1]. Though it is not stated directly, it treats the problem from constructal point of view. Here in this paper, an exergetic analysis of the problem is undertaken. Our analysis begins with efficiency; then it is modified to account for the exergy analysis. It should be mentioned that this problem has not been treated before because the heat transfer aspects of it were not treated before.

Keywords: Gibrat's law, quantum, log-normal distribution, Pareto distribution, power law, scaling relation, skewed distribution, Zipf's law



**BIOENGINEERING THERMODYNAMICS: FUNDAMENTAL THEORY AND APPLICATIONS  
IN CELLULAR SYSTEMS AND CANCER ANALYSIS**

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**ABSTRACT**

This paper provides a comprehensive review and synthesis of the foundational thermodynamic principles governing bioengineering thermodynamics in living cells, with particular emphasis on entropy generation, irreversibility, and the fluxes of heat and matter (ion) through cellular membranes. We develop a rigorous mathematical framework that integrates classical thermodynamics with cellular biophysics, encompassing key concepts such as entropy generation rate density, exergy analysis, and thermo-electrochemical potentials. Building on this theoretical foundation, we explore novel applications in cancer research, focusing on the role of thermal resonance phenomena and electromagnetic field interactions in modulating cellular proliferation dynamics. Experimental validations are presented to substantiate these effects, alongside a discussion of their implications for the design of targeted therapeutic strategies.

By bridging physics, biology, and thermodynamic engineering, this work establishes bioengineering thermodynamics as a promising interdisciplinary paradigm for advancing our understanding of cellular processes and developing innovative biomedical support for present anticancer therapies. Indeed, cancer research is increasingly interdisciplinary, integrating physics, chemistry, biology, and engineering. A new thermophysical approach utilising electromagnetic fields to inhibit cancer cell growth is proposed. This method focuses on heat transfer between cancer cells and their surroundings, introducing heat transfer resonance as a key factor in controlling cell growth.

**Keywords:** Bio-engineering thermodynamics; Cancer; Entropy; Irreversibility; Heat and mass fluxes

**FROM MOLECULAR AND CELLULAR BIOENERGETICS TO ECOLOGY: A  
THERMODYNAMIC APPROACH TO LIVING SYSTEMS**

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**ABSTRACT**

The nonequilibrium coupled processes of oxidation and ATP synthesis in the biological process of oxidative phosphorylation (OXPHOS) are fundamental to all life on our planet. These steady-state energy transduction processes – coupled by proton and anion/counter-cation concentration gradients in the OXPHOS pathway generate ~95 % of the ATP requirement of aerobic systems for cellular function. The rapid energy cycling and homeostasis of metabolites involved in this coupling are shown to be responsible for maintenance and regulation of stable nonequilibrium states, the latter first postulated in pioneering biothermodynamics work by Ervin Bauer between 1920 and 1935. How exactly does this occur? This is shown to be answered by molecular considerations arising from Nath's torsional mechanism of ATP synthesis and two-ion theory of energy coupling developed in 25 years of research work on the subject. A fresh analysis of the biological thermodynamics of coupling that goes beyond the previous work of Stucki and others and shows how the system functions at the molecular level has been carried out. Thermodynamic parameters, such as the overall degree of coupling,  $q$  of the coupled system are evaluated for the state 4 to state 3 transition in animal mitochondria with succinate as substrate. The actual or operative P to O ratio, the efficiency of the coupled reactions,  $\eta$ , and the Gibbs energy dissipation,  $\Phi$  have been calculated and shown to be in good agreement with experimental data. Novel mechanistic insights arising from the above have been discussed. A fourth law/principle of thermodynamics is formulated for a sub-class of physical and biological systems. The critical importance of constraints and time-varying boundary conditions for function and regulation is discussed in detail. Dynamic internal structural changes essential for torsional energy storage within the  $\gamma$ -subunit in a single molecule of the FOF1-ATP synthase and its transduction have been highlighted. These results provide a molecular-level instantiation of Ervin Bauer's pioneering concepts in biological thermodynamics. In this paper, we study the horizontal isothermal cylinder between vertically insulated plates. This problem from a heat transfer point of view was analyzed [1]. Though it is not stated directly, it treats the problem from constructal point of view. Here in this paper, an exergetic analysis of the problem is undertaken. Our analysis begins with efficiency; then it is modified to account for the exergy analysis. It should be mentioned that this problem has not been treated before because the heat transfer aspects of it were not treated before.

Keywords: Bioenergetics, biothermodynamics, Ervin Bauer, heat transfer, physics, life, Gibbs energy

**THERMODYNAMICS 2.0: THE PRINCIPLE OF GREATEST ACTION AND THE BIOLOGICAL  
MAXIMUM PRINCIPLE**

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**ABSTRACT**

Living organisms sense their distance from thermodynamic equilibrium and harness changes in their energy state and environment to sustain vital functions. The driving force behind this capacity is their ability to regulate extropy—a concept that incorporates Schrödinger's negentropy, summarizes all thermodynamic forces, and includes a measure of distance between the system and its environment. On this basis, thermodynamic systems fall into two classes: equilibrating systems (Thermodynamics 1.0), which minimize this distance, and self-governing systems (Thermodynamics 2.0), which maximize it.

Biochemical research shows that biomolecules operate under principles of maximal economy, efficiency, and simplicity for self-regulation, organization, and replication. These principles serve the continuous upchargin of free energy that underpins biological agency. Following the methodology that has driven the success of physics, Ervin Bauer formulated a universal principle of biology in thermodynamic terms—directing biological work uphill and channeling free-energy surplus toward biological ends.

By reconciling Bauer's principle with the principle of least action, and generalizing it by treating the action's endpoint as a free variable to reflect biology's goal-driven nature, I arrive at the principle of greatest action, expressed in terms of extropy. This interdependence reflects the hierarchical nesting of Thermodynamics 2.0 upon Thermodynamics 1.0.

Evolution proceeds from simple, passive physical entities toward increasingly embedded, complex, and active systems—thus manifesting biology's maximum principle itself. Among species, humans are the most cooperative, the most deeply embedded in nature, the most complex, and capable of the widest agency. Because the maximum principle attains its fullest expression in humans, it paves the way for a social science grounded in nature—and, through that, for a comprehensive integration of the natural and social sciences.

**Keywords:** negentropy, extropy, Bauer principle, principle of greatest action, agency, evolution



**THERMODYNAMICS, SYSTEMS THEORY, LIFE AND THE ENERGETIC PLURIVERSE**

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**ABSTRACT**

This paper proposes an integration of systems theory and thermodynamics, providing a framework for the fundamental characteristics of life, its evolution and its organization. By exploring the thermodynamic basis of emergence, self-organization, sub-optimality, non-linearity and complex feedback, we examine the thesis that complex systems are emergent outcomes of a thermodynamic universe. Since the laws of thermodynamics and systems theory are thought to operate across the Universe, they form a framework with which to explore the emergence of life, its evolution, behaviour and ecology from an energetic basis both on our planet and beyond. Rather than a form-dominated, structural, reductionist approach, gathered around the extended phenotype, a systems approach may offer a much more profound understanding of life as a functional, emergent outcome. The paper concludes with an exploration of a living pluriverse, where energetic gradients incident upon our planet lead to transformations of ecological behaviour, driven by thermodynamic economics.

Keywords: complex systems theory, emergence, non-linearity, pluriverse, self-organization, sub-optimality, thermodynamic economics



**COMPLEXITY REDUCTION AND CONCEPT DISCOVERY: LESSONS FROM  
THERMODYNAMICS AND MOLECULAR BIOLOGY**

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**ABSTRACT**

Science is built upon a hierarchy of concepts that simplify complex phenomena at scales ranging from atomic interactions to populations to the origin of the cosmos. The most useful concepts are those that retain the essential features of complexity at one scale to provide simplifying clarity at a larger scale. For example, the concept of valence electrons captures the crucial characteristics of electronic shell structure and the Pauli Exclusion Principle to simplify the quantum mechanical interactions that determine molecular structures. The fields of molecular and cellular biology have developed a powerful set of concepts to describe how genetic information encodes molecular interactions and how cellular functions are distributed between organelles. However, very few simplifying concepts have emerged at the cellular mesoscale, a range of scales larger than molecular feedback circuits (for example, the lac operon) and smaller than organelles. This “mesoscale conceptual gap”, is a major factor inhibiting research in cancer, aging, and other maladies caused by malfunction at the mesoscale.

The development of thermodynamics provides a valuable case study in concept discovery. This talk looks at the approaches used in the 19th century and compares them to the workhorse methods of modern cellular biology. A major difference is the prevalence of bottom-up versus top-down studies. I argue that this shift is responsible for the persistence of the mesoscale gap, and similar gaps in other fields, despite the prevalence of experimental methods capable of probing systems with almost arbitrary precision.

**Keywords:** complexity reduction, hierarchy, levels of organization, biology, thermodynamics

**HEALTH AND NEUROSCIENCES – A NONADDITIVE-ENTROPY APPROACH FOR  
DIAGNOSIS AND MORE**

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**ABSTRACT**

A generalization of Boltzmann-Gibbs (BG) statistical mechanics has, since 1988, been grounded on nonadditive entropic functionals, such as  $S_q$ ,  $S_{\text{delta}}$ , and various others. A brief introduction and some recent applications to health and neurosciences (through analysis of human EEG and deep-brain microelectrodes) will be overviewed. In addition to those, a connection between this generalized statistical mechanics and the successful BG-based theory of critical phenomena will be presented as well, which implies a reflection on the concept of infinity in natural sciences. Bibliography in <https://tsallis.cbpf.br/biblio.htm>

**Keywords:** entropy, neuroscience, Tsallis entropy, statistical mechanics, nonadditive entropy

## THE THERMODYNAMIC ORIGIN OF MOLECULAR INFORMATION

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### ABSTRACT

Origin-of-life theories, including the RNA-World hypothesis, simply assume that DNA and RNA intrinsically carry information. They avoid explaining how such information-bearing relationships could have evolved from scratch, before any transcription and translation apparatus existed to interpret their structures. In this presentation I describe a hypothetical proto-life process called “autogenesis” that provides the context in which a molecule's structure can become exapted to record and convey information about other molecular relationships. It assumes that nucleotide monomers like ATP and GTP were initially produced as byproducts of autogenic catalysis and initially retained because of their energy capture and transfer capacity. The unbound free energy of nucleotides can, however, be deleterious to a relatively stable complex molecular system, but when polymerized so that phosphates are bound between sugar molecules, the resulting RNA molecule becomes relatively non-reactive. In polymeric form, an RNA molecule can assume both linear and 3D configurations depending on surrounding conditions. In its 3D configuration, an RNA polymer can serve as a catalyst that biases the probability of specific interactions due to the way it binds other molecules. Because the 3D folding of an RNA polymer is determined by the affinities of complementary bases, there is a precise correlation between a polymer's linear sequence and its 3D configuration. This correlation enables a replicable polymer sequence to map to a specific catalytic function; thus providing a plausible de novo origin of molecular information that would be selectively favored because of the energetic advantage of the correlated catalysis.

Keywords: information, autogenesis, affinity, energetics, correlated catalysis

**SELF-ORGANIZATION IN DISSIPATIVE SYSTEMS: INSIGHTS FOR NOVEL TECHNOLOGIES**

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**ABSTRACT**

The life sciences often appeal to machine metaphors to understand physiological and psychological processes. Organisms are not traditional machines; the physics intrinsic to machines is ontologically distinct from that of organisms. The study of living systems thus benefits from the study of members of their proper physical class, namely, far from equilibrium self-organizing systems. We have demonstrated that traditionally essential properties of life – end-directedness, order-production, self-maintenance, and normativity – are natural consequences of the physics of dissipative systems. In addition to rethinking old quandaries in the life sciences, this work may yield new ways of designing technologies that instantiate useful qualities of living organisms. We review the properties of dissipative structures that set them apart from machines, and which yield these life-like qualities, and speculate on how the physics of self-organization might inform new design principles for future technologies.

Keywords: self-organization, dissipative systems, biotechnology, design principles



**VARIATIONAL PRINCIPLES: A UNIFYING PERSPECTIVE ON CLASSICAL AND STOCHASTIC THERMODYNAMICS**

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**ABSTRACT**

Variational principles provide a unifying framework for the formulation of physical theories. While traditionally associated with reversible dynamics, recent developments have extended this viewpoint to nonequilibrium and stochastic systems. In this talk, I will present a variational formulation of nonequilibrium thermodynamics and its extension to stochastic thermodynamics. The resulting framework, inspired by the Lagrange–d’Alembert approach, provides a unified treatment of both finite-dimensional and spatially extended systems. I will show how this formulation establishes new structural connections in stochastic thermodynamics, particularly between the Second Law, fluctuation–dissipation relations, and local detailed balance.

Finally, I will discuss how this variational framework provides a systematic foundation for thermodynamically consistent modeling and structure-preserving numerical discretizations.

Keywords: Variational principles, Lagrange–d’Alembert, stochastic thermodynamics, detailed balance

## EXPERIENTIAL THERMODYNAMICS: A BRIEF INTRODUCTION

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### ABSTRACT

Classical thermodynamics describes the lawful behaviour of energy exchange, work and organisation in physical systems from an *extrinsic*, third-person perspective—governed by principles of conservation, entropy, and equilibrium that all physical processes obey. 'Experiential thermodynamics' proposes that these same energy-work processes may have a complementary *intrinsic* aspect: i.e., there may be 'something it is like' for the system to undergo energy transformations from its own point of view and these may affect how it evolves and self-organises. Just as classical thermodynamics unified diverse phenomena (heat, work, chemical reactions) under common principles, experiential thermodynamics investigates whether systematic, lawful relationships exist between thermodynamic parameters and experiential properties.

The framework hypothesizes that measuring energy exchange, work rates, and their temporal-spatial organization in material systems—including neural systems— provides indirect access to experiential dimensions such as intensity, valence, and temporal dynamics of felt experience. If such dimensions are lawfully governed, they should respect established thermodynamic principles: experiential processes wouldn't violate conservation laws or introduce new causal forces. Rather, they would be the intrinsic complement of processes already described extrinsically by thermodynamics.

The research program seeks to identify invariant correlations between thermodynamic variables and experiential states in systems of various kinds, including living systems. One potential outcome is to derive new fundamental principles analogous to how Boltzmann connected macroscopic temperature to microscopic kinetic energy—but connecting extrinsic energy measures to intrinsic experiential properties. This could represent an extension of thermodynamics into previously uncharted territory: the felt, experiential nature of certain biophysical processes.

Keywords: experiential thermodynamics, extrinsic, intrinsic properties, system, energy transformation

## EVOLUTION, THROUGH THE LENS OF THERMODYNAMICS

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### ABSTRACT

Modern science still did not give us a satisfactory empirical explanation of increasing complexity in living beings through the evolutionary history. This question poses itself when comparing simple prokaryotic cells with more complex eukaryotic cells or comparing these with animals or plants or the most complex phenomena, e.g. consciousness and human language. The present scientific work relies on the hypothesis that at the beginning in the origins of life the evolution had to first involve autocatalytic systems, which only subsequently acquired the capacity of genetic heredity. Replication, transcription and translation that are used to transfer information from genes doubtlessly represent a special and very sophisticated type of catalysis or auto-catalysis. According to great philosopher Friedrich Nietzsche, each specific organic, and in a wider sense inorganic body as well, strives to dominate the whole space with its power and repulse anything that defies such expansion. It, of course, also resists the similar tendencies of other bodies. In the final phase, the process changes in harmonization with those "bodies" that resemble it or are related to it. On the first sight this looks rather weird, since each body is constrained with boundaries. However, if we view life as an interconnection of thermodynamic stabilization and kinetic factors that accelerate catalysis, with simultaneous understanding of life as a dynamic balance that is far distanced from thermodynamic equilibrium. Can then the initially mentioned syntagm of Nietzsche be further broadened to include the far from equilibrium thermodynamical system (FFE) without precisely defined boundaries that struggles to use its power and information content to dominate over the whole space and out-compete other systems or absorb them. If we consider the division of the system in its broadest sense so that the division does not necessarily include creation of equal parts, then we can, while considering the aforementioned syntagm, treat it as the basic generator of diversity. At same Friedrich Nietzsche proposed that in the Darwinian mode of evolution the winners are the most common and the lowest entities. Based on above mentioned premises, we have proposed following hypotheses: on the flow of information from environment to the biological system, on the molecular evolution of biocatalysers, translation, origins of life, increasing of complexity through evolution and definitions of life and consciousness and on possible solution of Chalmers' hard problem of consciousness.

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## BIOLOGICAL THERMODYNAMICS

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### ABSTRACT

This talk is all about the special role of thermodynamics in bioenergetics referring the coupled catabolism and anabolism in living systems, in which energy metabolism of production, conservation, and conversion take place. Classical thermodynamics views 'nature' as decaying toward global equilibrium and reaching maximum entropy in a closed system in accordance with the second law of thermodynamics. Biological systems operate far from equilibrium under constant supply of energy, material, and information, resist decay to equilibrium, and increase specialization and organization in time. They can create "order from disorder" by using the inherited information in genes, which links biology into thermodynamics.

As Schrödinger (1944) proposed, the study of living systems from a nonequilibrium perspective would reconcile biological self-organization and thermodynamics. This is in line with the second law of thermodynamics, which states that a finite amount of organization may be obtained at the expense of a greater amount of disorganization in a series of interrelated (coupled) spontaneous changes. One of the best examples of this is catabolism with anabolism that are mutually coupled through the specific mechanisms and intracellular phosphate potential. Catabolism pathways generate energy and carbon dioxide from the growth-supporting energy source of large biomolecules. Anabolism pathways, in turn, utilize this energy for synthesizing macromolecules and biomass from low-molecular-weight substrates in bioenergetic pathways. Regulation and synchronization of bioenergetics within an open nonequilibrium system ensure resilience and may be explained by thermodynamics as energy science.



## MAINTAINING ORDER FAR FROM EQUILIBRIUM: ENTROPY-REDUCING MECHANISMS IN HIGHER EDUCATION SYSTEMS

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### ABSTRACT

Higher education is increasingly described as a complex adaptive system. Over the past two decades, concepts such as complexity, systems thinking, system dynamics, resilience, self-organization and emergence have been applied to learning, educational change, institutional governance and university management. While these approaches have generated valuable insights, they remain largely fragmented, focusing on different levels of analysis—from classrooms and academic units to entire institutions—and employing diverse conceptual languages. This paper argues that there is a need for a coherent meta-framework capable of positioning these complementary perspectives within a broader theoretical landscape.

The paper explores whether concepts derived from non-equilibrium thermodynamics can contribute to such a framework. Rather than treating thermodynamic terminology as a source of appealing metaphors, it seeks structural correspondences between physical and social systems. Following Alan Sokal's well-known critique of the misuse of scientific concepts in the humanities and social sciences, the proposed framework deliberately avoids superficial analogies and instead asks whether selected concepts from thermodynamics and synergetics can serve as rigorous heuristic tools for understanding the dynamics of higher education systems. It builds on the intellectual tradition of Ilya Prigogine, Grégoire Nicolis and Hermann Haken, while acknowledging later methodological developments, including the application of synergetic thinking to science and education by V. G. Budanov.

The central hypothesis is that universities may be understood as open, knowledge-intensive systems maintained far from equilibrium through continuous exchanges of people, knowledge, resources and legitimacy with their environment. Their long-term resilience depends on entropy-reducing mechanisms operating at multiple organizational scales. Beyond well-recognized processes such as knowledge renewal, feedback, quality assurance and international collaboration, particular attention is devoted to mesoscopic structures—academic departments, research groups, disciplinary communities, accreditation systems, Communities of Practice, professional networks and university alliances—which mediate between individual actors and the institution as a whole. These relatively stable structures preserve institutional memory, absorb external perturbations, facilitate self-organization and enable adaptive change. The explicit recognition of this mesoscopic level is proposed as a distinctive contribution to existing complexity-based approaches to higher education.

The framework is informed by the author's experience at the interface of theoretical physics and higher education policy: early research in non-equilibrium thermodynamics and complex systems, followed by more than three decades of involvement in university governance, European higher education reforms and international academic cooperation. By identifying concrete institutional mechanisms that sustain organizational coherence under continuous external perturbations, the paper aims to contribute both to the emerging dialogue between thermodynamics and the social sciences and to the development of a more integrative theoretical foundation for higher education studies.

**TEMPERATURE COMPENSATION BY THE KAIB PROTEIN IN THE CYANOBACTERIAL  
CIRCADIAN CLOCK**

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**ABSTRACT**

The cyanobacterial circadian clock relies on the metamorphic protein KaiB, which transitions reversibly between a ground-state fold (gsKaiB) and an unstable fold-switched fold (fsKaiB). This fold-switching event creates a critical time delay in the oscillator's negative feedback loop. In this presentation, we explore the thermodynamics and kinetics of KaiB fold switching, investigating its underlying mechanism and temperature dependence.

Using a variant optimized for NMR, we demonstrate that the stability of gsKaiB increases with temperature relative to fsKaiB. Furthermore, the activation free energies for the forward and reverse transitions exhibit opposing temperature dependencies. Notably, the Q10 value for the gsKaiB to fsKaiB transition is nearly three times smaller than that for the reverse transition.

To elucidate the structural mechanism, we used native-state hydrogen-deuterium exchange NMR, revealing that fold switching involves both partially and completely unfolded intermediates. The isomerization of conserved prolines constitutes a rate-limiting step for this transition. We will discuss how this temperature-dependent fold-switching mechanism impacts temperature compensation, a defining hallmark of circadian clocks.

**Keywords:** circadian clock, protein fold switching, temperature compensation, hydrogen-deuterium exchange, proline isomerization

## **THE MONETARY MACROECONOMICS OF CELLULAR METABOLISM**

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### **ABSTRACT**

The evolutionary origins of metabolism have been challenging to study, not only because it is hard to precisely determine the sequence of key events that occurred billions of years ago but also because biology is lacking in general laws that would otherwise provide us some predictive power. To this latter regard, we may gain insights from studying an analogous system, a monetary macroeconomy, the evolution of which is comparatively better understood. Cell metabolisms are, in many ways, microcosms of macroeconomies. Reactions have energy prices, and Terrestrial biochemistry has even evolved to use a numeraire, ATP, in much of its metabolic activity. Indeed, ATP is often colloquially known as “the energy currency of the cell.” Output gaps can occur when bioenergetic supply and demand are misaligned. Cells can even exhibit the bioenergetic equivalent of business cycles. Accordingly, in this paper, I use principles of monetary macroeconomics to derive evolutionary attractors generic to metabolisms. I describe how interest rates and inflation arise in a metabolic economy. I show how organisms face a natural interest rate that affects their evolutionary freedom and how natural selection entails that organisms follow a metabolic analog of the Taylor rule. Importantly, just as the zero lower bound constrains the monetary policy of central banks during recessions, so too does it constrain the adaptability of life during negative environmental shocks.

Keywords: bioenergetics, econobiology, evolution, macroeconomics, monetary economics



**EFFECT STRUCTURE OF EQUATIONS OF STATE: A NEW THEORETICAL FRAMEWORK  
FOR THERMODYNAMICS AND ITS APPLICATION TO DEMAND-SIDE ECONOMICS**

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**ABSTRACT**

We propose a conceptual framework for the effect structure of equations of state (EoS), represented by a set of diagrams and governing rules, to establish criteria for identifying empirical relationships that qualify as equations of state. The proposed framework is applied to a closed system of consumers, leading to the formulation of an EoS for demand-side economy. Within this framework, equations of state are systematically classified into three distinct categories according to their effect structures. The manifold underlying the thermodynamic formulation of demand-side economics is explicitly identified, and formal analogies between thermodynamic systems and consumer systems are established. New thermodynamic-economic quantities, including total wealth, generalized utility flow, generalized utility stock and generalized consumer value surplus, are introduced and rigorously defined. The conventional microeconomic concept of consumer surplus is critically reexamined and reformulated in terms of generalized consumer value surplus. Furthermore, the classical Smith's law of demand is interpreted as a particular case corresponding to an isothermal process within the proposed thermodynamic paradigm. The limiting behavior of the absolute-zero demand-side economic temperature is examined as the boundary state of the proposed framework. At this limit, economic value, asset ownership, generalized utility flow, and the incentive to pursue further utility are absent, implying the cessation of demand-driven economic activities. Finally, an econometric framework for empirical estimation and validation of the proposed consumers' equation of state is developed.

Keywords: effect structure, equation of state, thermodynamics, demand-side economics



**THE MISSING DIMENSION OF MODERN HEALTHCARE: THE SCIENCE OF COHERENCE**

**Mitchell Abrams**

Michael G Degroote School of Medical Sciences, McMaster University, Canada

**ABSTRACT**

Modern medicine has transformed the diagnosis and treatment of disease, yet many of today's greatest health challenges, including chronic illness, mental health disorders, and burnout, remain inadequately addressed by a purely biomedical model. This presentation explores a missing dimension in healthcare: the role of coherence within complex living systems.

Drawing from Dr. Mitch Abrams' personal journey through open-heart surgery, together with research in heart-brain communication, psychophysiology, and compassion science, this talk examines the heart as far more than a mechanical pump. Emerging evidence suggests it plays an essential role in emotional regulation, resilience, social connection, and human flourishing.

Building from individual to collective coherence, the presentation explores how our internal physiological and emotional states influence relationships, communities, and ultimately population health. Abrams will introduce the Global Heart Sync, a non-profit international initiative exploring how cultivating coherence can strengthen wellbeing while fostering greater compassion, connection, and collective resilience.

Integrating medicine, neuroscience, and the emerging paradigm of unity science, this presentation offers a vision of healthcare that extends beyond treating disease toward cultivating the conditions that allow individuals and societies to flourish.

Keywords: collective coherence, physiology, integrative medicine, healthcare, unity of science

**THE ENTROPY TRAP: A PRACTITIONER'S INSTRUMENTS FOR MEASURING STORED  
STRESS IN FINANCIAL SYSTEMS**

**Mickey M. Maini**

Solstice Laboratory, Dubai, UAE

**ABSTRACT**

I am a practitioner, not a physicist. I run my own capital through a research group in Dubai that takes ideas from thermodynamics seriously enough to build instruments around them and test them. This talk reports what we built and what it shows.

The core idea is simple. Markets shed stress through falling prices, defaults, and failure. These are exits, not malfunctions. When policy blocks the exits with rate cuts, bailouts, and controls, the stress does not disappear. It is stored. Each rescue buys calm today at the price of a larger problem tomorrow. We call this the Entropy Trap. Forests under fire suppression behave the same way: fewer small fires, bigger eventual ones.

The idea predicts things we can check: calmer markets that produce more extreme surprises; rescues that work less well each time; and governments escalating through the same sequence of tools, from Rome to Rio, today: monetary, fiscal, regulatory, political, coercive.

I will show how we read this in practice: watching a variable's speed and change of speed rather than its level, and watching the exits directly. And I will end with three problems I cannot solve alone, our data, and an open offer of collaboration.

Keywords: entropy, financial stability, policy intervention, econophysics, measurement

**EXACT EVOLUTION LAW FOR ACTION-WEIGHTED PATH ENSEMBLES AND THE  
DYNAMICS OF SELF-ORGANIZATION**

**Georgi Yordanov Georgiev**

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**ABSTRACT**

Self-organizing open systems sustained by source--sink fluxes transform stochastic motion into ordered behavior, yet a general dynamical criterion governing this process has not been established. This paper derives an exact kinematic law for evolving action-weighted canonical path ensembles, and decomposes the dynamics of the ensemble-average action. In the precision-driven regime, the evolution closes: the rate of change is governed by the action variance, so increasing selectivity concentrates probability weight toward lower-action trajectories, causing the average action to decrease monotonically and behave as a Lyapunov-type quantity. Constant and decreasing selectivity lead to stationary and broadening behavior. Endogenous reduction of the average action defines self-organization, while externally prescribed modulation defines controlled ensemble evolution. The framework further admits system-dependent realizations of selectivity dynamics, including reconstruction from observable statistics and feedback-driven evolution, without modifying the underlying kinematic law. By using stochastic action as the organizing trajectory-level quantity, the approach connects path-ensemble organization to stochastic least-action ordering while yielding measurable diagnostics, finite-time constraints, and falsifiable signatures in open stochastic systems.

Keywords: exergy, constructal law, heat transfer, exergy analysis



**THERMODYNAMIC CHARACTERIZATION OF BIOLOGICAL CELLS TO INFER ABOUT THE SCIENCE  
AND TECHNOLOGY OF LIFE**

**Ram Poudel**

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**ABSTRACT**

Thermodynamics is a universal science. The language of thermodynamics is energy, free energy, and its derivatives, such as entropy and power. The physical theory of thermodynamics reigns across a full spectrum of non-living objects as well as living beings.

Biological cells are basic units of life. Characterization of a biological cell is a first step toward a science and technology of life and its collective. We model a biological cell as a biological dipole consisting of molecular engines (BE), pumps (B $\exists$ ), and energy storage (AH) that help sustain the cell. Following the model of a unified science [1], we characterize a biological cell in terms of its individual property – the dipole strength measured in Ampere.meter. This characterization leads to the formulation of Hamiltonian of the cell in its collective (with tissue, or organism). The elementary field of a collective of cells satisfies the Klein-Gordon equation. Hence, a static description of the dynamics of interacting cell systems can be formulated in terms of an auxiliary field we have named the social field.

Hamiltonian space is defined by an ordered pair of its kinetic energy (K) and potential energy (U). The sum of the coordinates represents the total energy of the system. The collective defines the potential energy, and the oscillation of the center of mass defines the kinetic energy. A master equation based on the power in the Hamiltonian spacetime provides important insight into the growth and evolution of life.

This biomachine model of a cell consists of subsystems (BE, B $\exists$ , AH) that operate in a cycle between two potentials. There may be several dipoles within the cell at different length and time scales. We take a system approach [3], control volume analysis of thermodynamics, and refrain from guessing into organelle-level distribution of energy and matter. Instead, we focus on the sociology (interaction and interdependence) of cells to study dynamics at the phenomenological level.

The technology of life highlights the energy exchange among thermal, electrical, and electromagnetic systems. We present a new formalism for evaluating entropy associated with the life unit and its compliance with second law of thermodynamics. This formalism sheds light on why we don't have a synthetic biological cell. A theory of measurement is proposed to validate the model of the cell in terms of macroscopic observables such as cell membrane potential (volts) and dipole orientation (degrees) etc., utilizing experimental design and measurement in cell electrophysiology.

**Keywords:** science of life, Hamiltonian, social field, dipole, biological cell, technology



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