Freedom and Evolution

Preprint

Adrian Bejan

Duke University, United States

Presented at the Thermodynamics 2.0 | 2020
June 22–24, 2020

International Association for the Integration of Science and Engineering (IAISAE) is a non-profit registered in Colorado, United States

Conference Paper
IAISAE/CP-T2020-W113
June 2020

Freedom and Evolution

Preprint

Adrian Bejan

Duke University, United States

Suggested Citation
Bejan, Adrian.2020. *Freedom and Evolution: Preprint*. Superior, CO: International Association for the Integration of Science and Engineering (IAISAE). IAISAE/CP-T2020-W113. https://iaisae.org/wp-content/uploads/w113.pdf.

International Association for the Integration of Science and Engineering (IAISAE) is a non-profit registered in Colorado, United States

This article is available at no cost from IAISAE at www.iaisae.org/index.php/publications/

Conference Paper
IAISAE /CP-T2020-W113
June 2020

IAISAE prints on paper that contains recycled content.

Proceedings of the IAISAE 2020
International Conference on Thermodynamics 2.0
June 22-24, 2020 | Worcester, MA, USA

ICT2.0:2020-W113

FREEDOM AND EVOLUTION

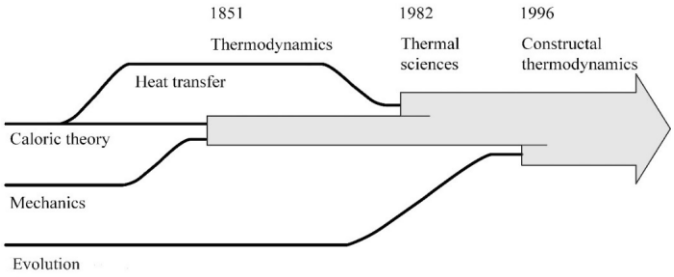
Adrian Bejan

Duke University, Durham, NC, USA

Keywords: Thermodynamics, Evolution, Freedom, Nature, Society, Science, Hierarchy

In this lecture, I introduce my new book *Freedom and Evolution: Hierarchy in Nature, Society and Science* [1]. This book joins my previous books on the thermodynamics of everything in nature [2-9].

Thermodynamics is the science of power—the power from heating from fuels, or food in animals, and the heating and cooling from power, as in refrigeration and air conditioning. My latest contribution to thermodynamics is the physics law of evolution, the constructal law, which accounts for all the changes that happen because of freedom in flow configurations.



Changes have direction in time, toward configurations that provide greater access to what flows. Changes are everywhere, in the geosphere, the biosphere, and the human sphere with all its social organization, science evolution, and technology evolution.

Nature impresses us with images of evolutionary changes that repeat themselves innumerable times even though 'similar observations' are not identical to each other. We recognize each universal tendency as one distinct 'phenomenon,' and we summarize each phenomenon with its own 'law' of physics, which serves as a 'first principle' in the organization of science.

Observations are many, and laws are few. The hierarchical organization of science is illustrated clearly by the evolution of thermodynamics to its current state. Observations of energy conservation, irreversibility and evolution are summarized as the first law, the second law and the constructal law.

Evolution is the defining phenomenon of nature. Everywhere we look what we see is evolving because it is free to move and morph. With no freedom, there is nothing, no design, no evolution, no time and therefore no future.

Freedom is everywhere because evolution (design change) is everywhere in the inanimate, animate and human realms. Yet, unlike evolution, freedom is not a scientific subject. It is as if scientists are afraid to speak the word 'freedom' even though every day they rely on the reality (the presence) of freedom.

For example, every single book of thermodynamics is filled with analyses and graphs of 'processes'. The definition of process is the change in the description (the 'state) of the system. Clearly, if the system is able to change, then it must have in its description the property called freedom.

It's not surprising that freedom and evolution have been overlooked by physics. The more common a physical presence, the more likely it is that it is overlooked. It happened this way with gravity, sound, turbulence, and fish swimming. It took time for questioners to be born, and for physics to expand over the newly identified territory.

The purpose of *Freedom and Evolution* [1] is to present the predictive theory of evolution. It is to establish firmly the concepts of freedom and evolution in physics. The approach I have chosen is that freedom is physics, not opinion. Freedom is physics, not the politicians' narrative. Evolution is physics, not the biologist's narrative. All the ideas and examples in *Freedom and Evolution* [1] were published based on peer review in physics, biology, and engineering science journals.

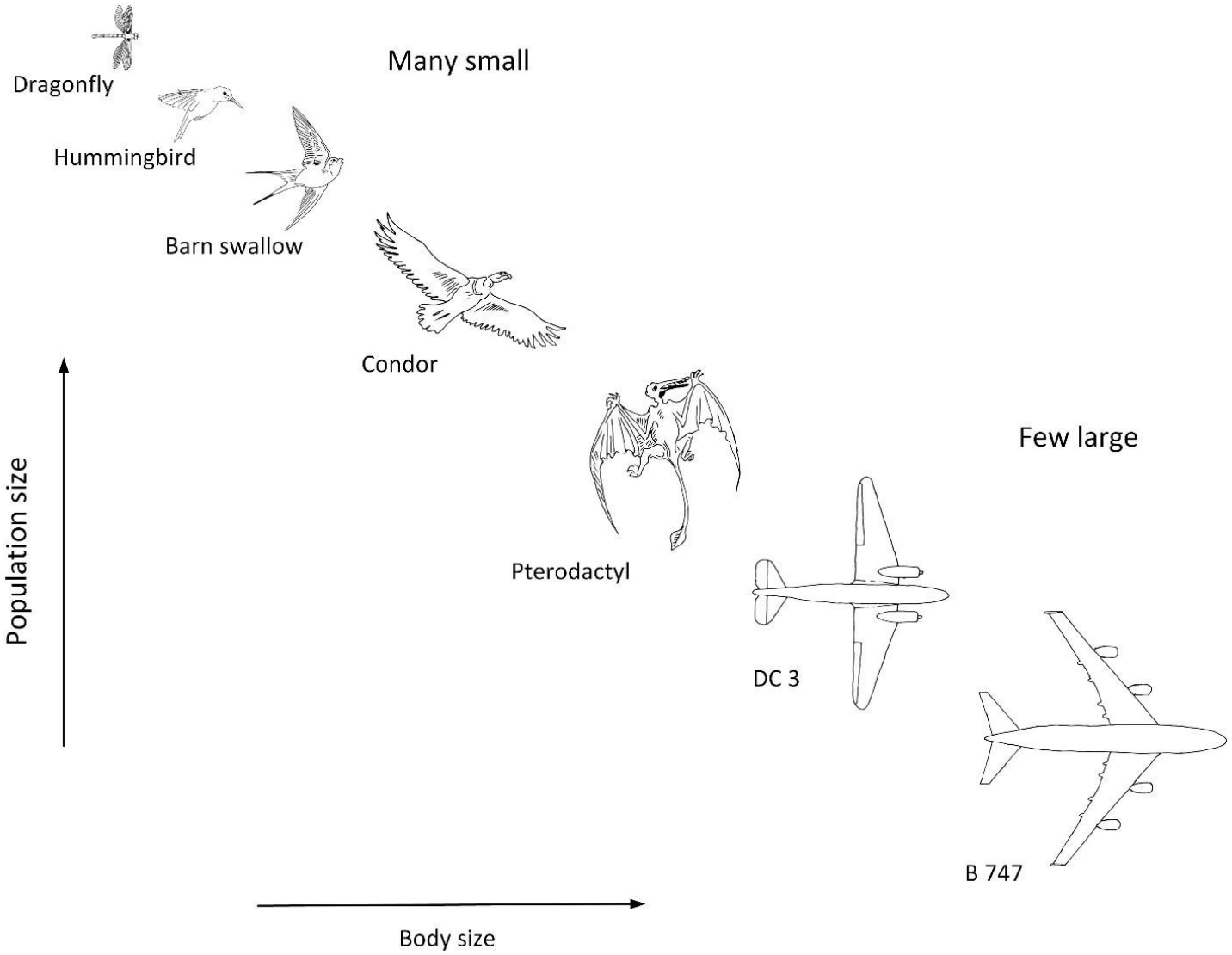
Like everything else that is physical (i.e., part of nature), freedom is measurable. Freedom is the measurement of how many physical features are free to be changed in the configuration of the system. Measurable is also the physical effect that the ability to change has on measures of system performance such as efficiency, power, robustness, resilience, and life span. In human-made designs, freedom is also measured as the 'degrees of freedom' that are present in the model (the facsimile) of a natural flow system. Degrees of freedom are those features that can be changed freely and independently of other features.

Science evolves because of freedom, and freedom thrives because of science. It is easy to create in freedom—just think of the history of art and science. Look at where artists and scientists were and where they lived and created. Their names speak of geography, history, culture, wealth, and the physical movement of free people with ideas and freedom to question and change the status quo.

The physics of freedom and evolution empowers the reader with a science that covers territories that so far were not associated with physics: economies of scale, diminishing returns, hierarchy, wealth, social organization, and the spreading of ideas and scientific thought. Empowerment happens in two ways: readers understand better the world around them, and they apply that understanding to effect change faster and more effectively.

Physics tells us why things must be the way they are, and also that they are the givens that you must know in order to improve life and society. Things that appear disconnected and random are fooling us: they are intimately connected, hierarchical, flowing woven together and along with us, and thriving because of freedom, organization, and evolution.

Society, for example, is an earth-size living organism. The larger city is a bigger and more efficient mover than the smaller. This is why when the city is thriving the smaller settlements and companies are joining the bigger, why people migrate from the countryside to the city, and why in the industrial age the global society is evolving from peasant to urban. When the city ceases to thrive, the migration is the other way, toward the countryside.



This view of science addresses head-on and nullifies contradictions that spring in our minds, for example, freedom versus inequality, freedom versus rules and discipline, rigid hierarchy versus evolution, rules versus random diversity, and evolution versus seemingly stable design.

Key is the image of evolutionary design, which makes one

think of movies of rivers flowing, animals running, pedestrians walking, and people riding on buses, trains, and airplanes. The unifying physics is that nothing moves unless it is driven. Pushing comes from power, from fuel and food. Once a natural system moves, it continually evolves its configuration toward flowing more easily. As systems evolve, grow, and become more efficient, they also become more complex. Why? Because joining and moving together requires less power than moving individually. This is the physics basis of 'economies of scale' and social organization.

The same physics principle accounts for the fact that river systems evolve into embroideries of small tributaries flowing into a major river, and why a peloton moves more quickly than an individual cyclist. The bigger stream, animal, and vehicle are more efficient movers than the smaller. The hierarchical system with many small and few large movers is more efficient than the 'one size fits all'.

The complexity, diversity, and apparent unpredictability of nature are distilled to three main ideas:

First, flow configurations (designs) are everywhere, around us and inside of us: tree-shaped flows, round cross sections, and rhythms such as inhaling and exhaling. Evolution of design is a universal, unifying phenomenon of nature, and it is predictable based on its own law of physics, the constructal law.

Second, nature is a flowing weave of 'engines' connected to power-dissipating systems that act as 'brakes'. The engines and brakes move hand in glove and evolve their configurations with freedom.

Third, humans and their contrivances (machines, artifacts, add-ons) are like everything else that moves and evolves on earth. None of the evolving nature would be possible without freedom and power to move.

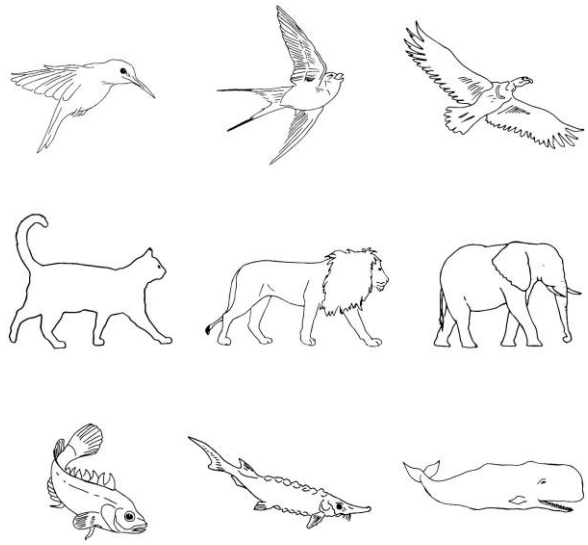
The diversity of hierarchical flow architectures covers the broadest spectrum accessible to human observation: all size scales, animate, inanimate, human made and not human made, and steady and time-dependent. Examples detailed in *Freedom and Evolution* [1] are river basins, human settlements (city rankings), sizes versus numbers of trees in the forest, university rankings, and rankings of highly cited authors.

The non-uniform distribution of wealth is predictable because it is due to the evolutionary architecture of all the streams of a live society. The physical movement on the surface of the earth evolves naturally as arborescent hierarchical flows. The GDP of countries all over the globe is proportional to human movement because it is proportional to the annual consumption of fuel, which drives all human movement. More economic activity means more fuel consumption.

Why does social organization happens by itself? Why does the organization become more hierarchical and unequal when the flows of society increase? Such questions are answered from physics with two models, one without human society (river basins) and the other with human society (the distribution of hot water over an inhabited territory). The results from the two models are similar, except that in the model with human society the distribution of flow is less unequal. The reason is that the overarching presence of purpose (objective) at the scale of society controls inequality. Inequality persists even when the natural hierarchy of channels is replaced everywhere by artificial one-size channels. The spreading of individual innovation events over the populated territory benefits the whole society, in addition to benefiting the innovator.

There is no contradiction between freedom and reliance on discipline. In fact, the opposite is true: the scientist who possesses the disciplines is the most free to venture into new domains of knowledge. Disciplines are essential, empowering, and liberating for the scientist.

Complexity, organization, and evolution in nature are most powerful and useful when pursued as a discipline. A discipline has precise terms, rules, principles, and usefulness. A drawing has size, meaning (message), and svelteness (thinness of lines). Drawings are useful when they are simple, easy to make, and not too large or too small. Icons and golden-ratio rectangles emerge from the human need to understand to communicate more easily and faster. This is why features that are being perceived as attractive and beautiful are worth keeping.



Why is there so much diversity? Why don't we all look the same? Why are our occupations and contrivances diverse and becoming even more diverse? The answer lies in the freedom that all flow architectures have in how they spread, migrate, interbreed, and combine with flow designs that they encounter in their paths. This happened to the human flow on the globe. Along the way, humans have diversified as specimens of one 'human and machine species'.

The diversification of the machine part in each of us is evident in modern and contemporary times as the evolution of science and technology. The diversification of mechanics into thermodynamics and its many subfields accounts today for engineering sciences of many kinds: mechanical, civil, electrical, chemical, petroleum, nuclear, aeronautical, and more. The diversity of the human and machine species is of the same nature as the evolution of 'niche construction' in animal evolution.

Evolution—its future and its past—can be predicted. Detailed in *Freedom and Evolution* [1] are three predictions: one animate (animal locomotion), another inanimate (river basins),

and the third about the human and machine species (aircraft). Many more predictions are available, for example, the cross sections of jets and plumes, the growth of snowflakes, the life span and life travel of animals and vehicles, the lung architecture, and the main measures of animal locomotion (speed, frequency, force). Fundamental, for physics, is that a large architecture is not a magnified facsimile of a small architecture.

Finally, if evolution is so ongoing and everywhere, why do so many things look as if they are stuck in time? The reason is the phenomenon of diminishing returns, which is observed in freely evolving flow architectures that have become 'mature.' New changes have only marginal effect on the broad outlook and performance of a mature architecture.

The evolution of science is a manifestation of the physics of freedom, access, and social organization. The ideas and the physical movement of the individual generators of ideas are organized non-uniformly, hierarchically on the earth' s surface. As society develops, it moves more, produces more, and generates more changes when it is endowed with freedom, free questioning, and self-correcting.

Many in academia make the mistake of equating the goodness of an idea with the number of authors who agree with that idea. The history of science proves this to be false. Science is not about counting people. All individuals are not equally imaginative. All ideas are not equally important. Science is not democracy.

Many make the mistake of equating the goodness of ideas with the volume of research funding, people hired, money spent, and buildings built. The history of science proves this to be false. Science is not the amount of money spent. Dollars spent are not equally important. When I read the scientific literature, I see names, dates and ideas, not budgets. Science is not accounting.

When I read the news of a huge research grant for a big research center, I predict that it will change nothing. The truly new, the svelte, beautiful, and valuable comes from the least expected source, which tends to be the unknown person with a zero budget. That's science again, and it is just like in competitive athletics: you have no idea what poor kid walks from the street onto the playing field. That is wonderful, it is the good news that sustains science and civilization.

The evolution of the physics of power (thermodynamics) shows that what works is kept as an add-on to the science that was. What is false is swept aside, and forgotten. This is the evolutionary morphing design of science. This is also why every once in awhile the scientific community is presented with a reality check, a new bird's-eye view that is suddenly useful as a guide to the new generations. Revisionism is checked, authority is questioned, fakes are exposed, mistakes are corrected, and this way a renewed appreciation of the discipline empowers the new generations. The stream flows better after the rotting tree log is swept out of the way.

Science is self-correcting because it is imbibed in freedom. This key truth of science needs to be broadly communicated to all, not just scientists.

Freedom to change is the track on which the evolution train runs to join the other trains of science. It is useful to know why the track is so 'smart' that it led the designs of geophysics and biology to levels of perfection that continue to amaze us.

It is critically important to know how to use the evolution track so that our own artifacts evolve faster and more economically to even higher levels of efficiency, so that our own life as the human and machine species continues to become more free.

ACKNOWLEDGEMENTS

This article was written during Adrian Bejan's term as recipient of the 2019 Humboldt Research Award.

REFERENCES

[1] A. Bejan, *Freedom and Evolution: Hierarchy in Nature, Society and Science*, Springer Nature, Switzerland, 2020.
[2] A. Bejan, *The Physics of Life: The Evolution of Everything*, St. Martin's Press, New York, 2016.
[3] A. Bejan and J.P. Zane, *Design in Nature*, Doubleday, New York, 2012.
[4] A. Bejan, *Advanced Engineering Thermodynamics*, 4th ed., Wiley, Hoboken, 2016.
[5] A. Bejan and S. Lorente, *Design with Constructal Theory*, Wiley, Hoboken, 2008.
[6] A. Bejan, *Shape and Structure, from Engineering to Nature*, Cambridge University Press, Cambridge, UK, 2000.
[7] A. Bejan, *Entropy Generation Minimization*, CRC Press, Boca Raton, FL, 1996.
[8] A. Bejan, G. Tsatsaronis and M. Moran, *Thermal Design and Optimization*, Wiley, New York, 1996.
[9] A. Bejan, *Entropy Generation through Heat and Fluid Flow*, Wiley, New York, 1982.