Perfection and Diversity in Evolution*

Adrian Bejan**

Abstract

This article explores the causal relationship from freedom to perfection (imagined) and diversity (observed). The presentation is with two examples of perfection and diversity over space and in time. The first is animal movement in all media. The second is a man walking his dog on a leash, which illustrates the decrease in diversity and performance (economy) that comes from coerced collectivization. If you truly want diversity, give the people freedom, not the leash.

Keywords: Nature, Freedom, Evolution, Perfection, Diversity, Collectivization, Constructal law.

Perfection and diversity

Why don't animals look the same? Why does nature 'select' diverse forms from diverse media (water, land, air), not from one template, and not of one size? Why don't they all perform the same way? After all, in the Darwinian struggle for 'survival of the fittest', clear winners must have been selected millions of years ago. Diversity is everywhere, around us, among us, and inside of each of us. Diversity is natural, a defining part of nature. It happens, by itself [1, 2].

What causes diversity? In this article I show that the answer comes from questioning these sayings from notable authors:

"The best is the enemy of the good." (Voltaire)

"Politics is the art of the possible, the attainable – the art of the next best." (Bismarck)

"Perfection is the enemy of progress." (Churchill)

When we first hear them, we take notice because they are counterintuitive. Most of us tend to associate the better performing with the more perfect.

Are these sayings true? This is a question of physics, not opinion. I address it in terms of the physics of evolutionary design (constructal law [3-9]) by focusing on the diminishing returns that come from adding more degrees of freedom to a moving (flowing, morphing) design that has already been 'perfected' thanks to existing degrees of freedom. Diversity emerges naturally, inevitably, and beneficially. In that direction of change, not everything is big, small, or one size. Before we continue, here are the main terms. They ask to be questioned, especially now when we hear about designing and implementing diversity by force, in society. Words that sound familiar are pleasing, but when they are repeated in unison by the nameless crowd I reach immediately for Webster's dictionary:

Perfection is a condition of complete excellence, faultless, most excellent. Perfection (from *perfectus*, in Latin) means complete in all respects, without defect or omission, flawless. While perfection does not happen, imperfection and diversity happen naturally, across the board.

Diverse comes from the Latin *diversus*, which is the past participle of the verb *divertere*, to turn aside, as something different, dissimilar. Diversified means varied. Diversity is the quality of variety, which in nature is infinite, immeasurable. That's something to think about, when you hear of only two classes, one against the other, the class struggle, not in harmony.

**Alocuțiune susținută la deschiderea lucrărilor Conferinței internaționale „Design in Nature and Evolution" (10 octombrie 2024, Aula Academiei Române)*

***Honorary Member, Romanian Academy, Duke University*

Diversity is common sense because it happens naturally, not artificially. The diversity we see around us is not the result of a dictate. Weeds appear among shrubs in the most carefully plated vineyard and apple orchard. Mutts are born every day. Mothers give birth to children who grow up to have amazingly diverse ideas.

Features and phenomena tend to go unnoticed if they are present everywhere. They are noticed only when they appear in contrast on a background filled with the usual stuff. They are noticed only if they are *unusual.*

Diversity is not unusual. It seems unusual every time we are forced to impose diversity on society at all levels, enterprise, university, competition in athletics, and the merit system. Whether this has a future is for the reader to conclude. To help, I decided to question the physics origin of diversity – why diversity happens naturally, why it is a phenomenon that has a mind of its own, and why it opposes any effort of being reduced to a few categories, by design.

Animal movement

There is a lot to say about the phenomenon of natural diversity and what causes it, therefore in this brief article I present just two illustrations, both from the animate realm. Numerous inanimate examples are like these two.

The first demonstration is made in simple terms (Fig. 1). The domain of animal diversity is immense because of the coexistence of many classes (bodies, groups, fluids) that move with freedom in space and time. The main features of animal movement are predictable [3, 10, 11]. The straight lines in Fig. 1 are from two predictions: the relations between animal speed and body size, and between body frequency and size. The body frequency refers to the cycle of body undulation, flapping wings, leg stride, and fishtailing. The two parallel lines distinguish between the environments in which animals move: water, land, and air.

Each line is the locus of points of 'perfection' found at the bottom of convex curves like the bucket curve in Fig. 2. Evident is the diversity that accompanies the theory (the straight lines) and the measurements of animal design. Like a hotdog on a stick, a cloud of data (the diversity) is supported by each theoretical line (the perfection). The data are attracted to perfection, but do not agree with perfection. In some cases, the disagreement is significant, causing the animal to be relegated to the status of 'outlier', which means residing outside the expected features of the natural design [12].

The measurements that filled the clouds confirm that the characteristics of animal movement are manifestations of the natural urge to evolve, to have access, and to spend less work per unit of distance traveled [3]. The animal tendency is to sense the difference between 'easy' and 'difficult', and to opt for what is easier. To choose the open door as opposed to the closed door is a manifestation of the urge to have access (life, freedom). To choose the closed door when behind the door lurks an enemy is a manifestation of the urge to have access (life, persistence, staying power).

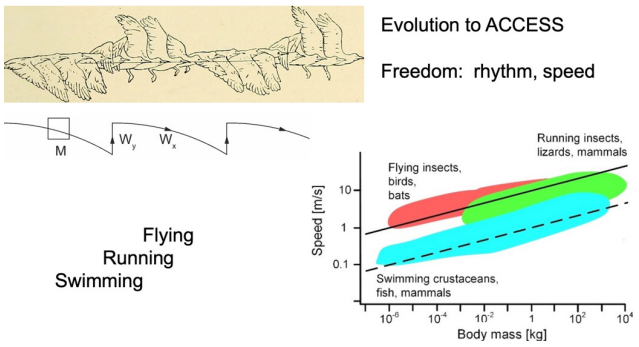

Figure 1. Bird flight at nearly constant altitude and speed is a faint zigzag caused by a cycle of work done in two directions, vertically and horizontally. The total expenditure of work reaches smaller values when a balance emerges between the two efforts, or between the time to lift and the time to glide forward. The clouds of data on the speed-mass graph refer to measurements [10].

The bucket-shape curve of work versus speed is due to the competition between two efforts that the animal must make to be able to change its location on Earth: the effort to lift itself against gravity, and the effort to get the environment out of the way, against drag. The lowest point on the curve (the minimum, the optimum) is a mathematical concept, not an animal.

The animal moves with diverse speeds and frequencies depending on the changes in its immediate vicinity (wind, weather, food, neighbor, danger). The animal senses the difference between easy and difficult, between far and near, and generally between attractive and repulsive [7]. Furthermore, different animals have different

lifestyles –herbivores, predators, scavengers, and so on. Even when considered as their own group, the herbivores live differently depending on their feeding pattern: grazers, tree fruit eaters, and rodents. The natural origin of diversity is why the biggest animals and vehicles are fast but not the fastest [12].

Greater access (speed, distance, economy) happens when the two efforts are in balance ($W_y \sim W_x$ in Fig. 2). To indicate a balance, I used the symbol "~", which does not mean equality but order of magnitude equivalence between W_y and W_x. Animals sense the difference between less effort and more effort, between access and obstacle, and between being free and in a cage. People sense the same difference, math, or no math. The difference brings them close to the balance, and that gives birth to the diversity and probability

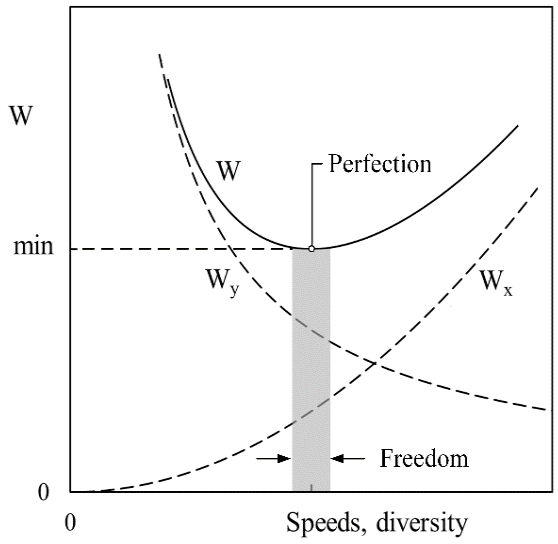

Figure 2. In animal flight the total effort per flapping cycle (W) is the sum of the two asymptotes, the work done vertically (W_y, to lift), and the work dissipated horizontally (W_x, to displace the immediate surroundings). The range of speeds for reduced work requirements is found in the vicinity of the intersection of asymptotes. The freedom to fly economically at speeds and rhythms in the vicinity of 'perfection' is the cause of diversity.

The ability to adjust the balance between the two efforts (W_x and W_y) is the single degree of freedom. In this simple model the flapping frequency (the rhythm) is not a second degree of freedom: it is an alternate way of expressing the balance between the two efforts.

The balance (the greater access) is evident in several ways, all measurable and predicted: flapping frequency, cruising speed, and total effort per unit of distance traveled. The relation between speed and body size for fliers is the straight solid line on the graph in the lower-right of Fig. 1. Invoking the same balance for swimmers leads to the theoretical scaling law shown as dashed line on the same graph. Fish lift weight, contrary to the common view that gravity does not matter to the fish. That view is correct only when the fish is motionless. The moving fish lifts the weight of the displaced water, to advance [10]. The body of available speed-mass data fills the red and blue clouds that hug the two lines and confirm the validity and broad reach of the theory.

A model that can be changed because of a single degree of freedom is represented by a single curve (e.g., Fig. 2), and does not capture nature completely. The moving animal is much more than a vehicle with speed and size. The animal is also a thinker and an engine, a steadfast discoverer of fuel (food) for its engine.

In the direction toward more realistic models, the necessary degrees of freedom multiply, and the two-dimensional plots of Figs. 1 and 2 are replaced by families of curves and surfaces in three or more dimensions. Diversity becomes broader, more complex, and more difficult to rationalize unless the mind possesses the seed – the idea – the physical source of diversity (freedom, imagined perfection), which is put on display even with the simplest model.

Collectivization

The second demonstration is based on the tendency of all moving entities to evolve toward more freedom and access in space and time. The freedom urge is universal, from the water held behind the dam to the dog walked by its master on a leash (Fig. 3). In the present context, the noun urge (from the verb *urgere*, to press hard, in Latin) means an inner drive, an impulse to do a certain thing.

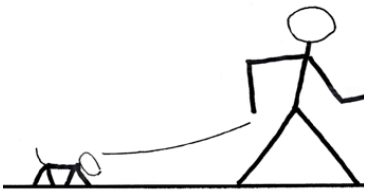

Figure 3. On a leash, the dog is not walking at its natural speed. Neither is the person holding the leash. Natural is the speed of the animal walking freely. The leash is a symbol of lack of freedom.

When free, without the leash, the man and the dog have their own bucket shaped curves and minima of effort versus speed (Fig. 4). On the abscissa, $x_1 = 1$ corresponds to the most economical speed of the man. The most economical speed for the dog is smaller than for the man because the dog is smaller ($M_2/M_1 < 1$).

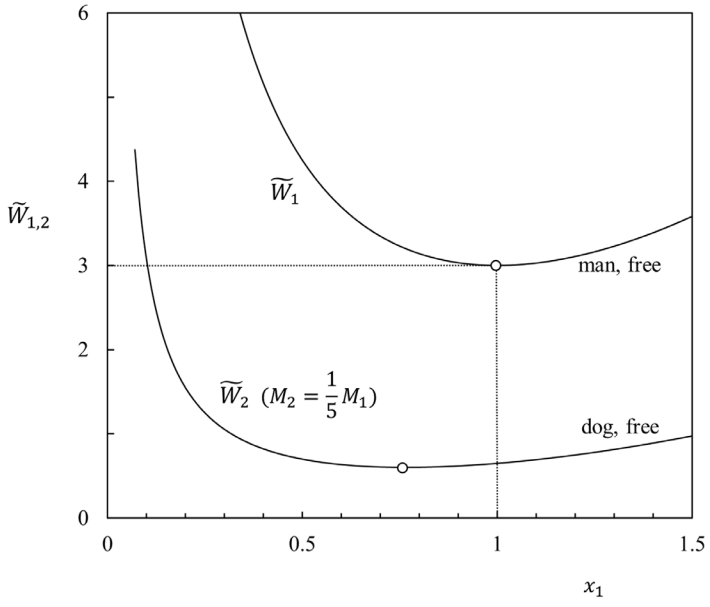

Figure 4. The effect of speed (the abscissa) on the efforts of a man and, independently, a dog. M_1 and M_2 are the sizes (masses) of the man and the dog, respectively.

With the leash, the dog and the man are coerced to walk at the same speed. At least one of them makes a greater effort than what is available at his most economical speed. The couple exerts a greater effort than when walking freely (Fig. 5).

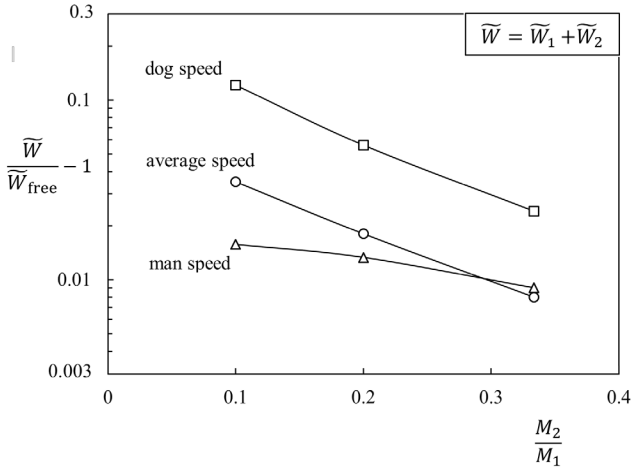

Figure 5. The combined effort of the man with the dog on a leash (W, on the ordinate) is always greater than when the dog and the man walk freely (i.e., as in Fig. 4, $W_{free} = W_{man,\,free} + W_{dog,\,free}$).

In sum, the physics of animal movement (life) teaches that when linked, the moving couple spends more work than when free. Participants in organized movement (society, life) are not equal. They move with less effort when they are not coerced to move as one, as in collectivized agriculture. Society is more economical when individuals are free to move, change, evolve [2].

To move free does not mean to move alone. People come together in hierarchical structures (hierarchies, flow) because it is good for their individual freedom, access, life, and staying power. This is the natural phenomenon of *economies of scale* [6]. which has also been predicted by invoking the constructal law. People come together voluntarily, not coerced.

The difference between economies of scale and the dog on leash (Fig. 3) is the difference between freedom and lack of freedom. The evolution of human society is in accord with this conclusion. The leash can be viewed as a metaphor for the forced collectivization of agriculture (and much of everything else) during communism, in the USSR and its satellites.

The intangibles are tangible

Most scientists regard human perceptions as intangibles – freedom, time, beauty, feelings, choices, and opinions – not belonging to a law of

nature. In these two examples [1, 2], and in [3-7], we discover that the intangibles are *tangible* and teachable as physics at the high school level.

Reality exists. The perceived is the reality of change, shape, object, and movement. Reality is subjected to test and validation everywhere. From a barn on fire, the horse, the pig, and the man run for their lives. The perceived change (fire *after* no fire) is the same because it is real, part of nature. It is not relative.

The idea of intangibles as physics is disruptive. Well, some disruption should be of great interest to all scientists, journals, and developers of AI, because without the ability to understand the physics behind perceptions it is not possible to create machines that approach natural human ability. The physics is evolutionary flow configuration with freedom to change. The artificial dog might end up running more efficiently, freely, nimbly, and faster than the natural dog, but only if it had more degrees of freedom, consciousness, and a longer time to evolve than a natural dog. In one word, never.

Freedom, access, imperfection, and diversity are physical and natural, bio and non-bio. Movement is set in motion by perceptions, feelings, and emotions. Instead of freedom, access, diversity and progress, people are more likely to sense a lack of freedom, access, diversity, and progress. If you want diversity, give the population freedom, not the leash.

Nature has a mind of its own.

Perfection: you may imagine it, but it never comes.

Diversity: you can't imagine it, but it always comes.

References

1. A. Bejan, *Perfection is the enemy of evolution*, *BioSystems*, Vol. 229, 2023, 104917.

2. A. Bejan, *The Physics of the Urge to Have Freedom*, BioSystems, Vol. 243, 2024, 105277.

3. A. Bejan, *Shape and Structure, from Engineering to Nature*, Cambridge University Press, Cambridge UK, 2000.

4. A. Bejan and J.P. Zane, *Design in Nature: How the Constructal Law Governs Evolution in Biology, Physics, Technology, and Social Organization,* Doubleday, New York, 2012.

5. A. Bejan, *The Physics of Life: The Evolution of Everything*, St. Martin's Press, New York, 2016.

6. A. Bejan, *Freedom and Evolution: Hierarchy in Nature, Society and Science*, Springer Nature, New York, 2020.

7. A. Bejan, *Time and Beauty*: *Why Time Flies and Beauty Never Dies*, World Scientific, Singapore, 2022.

8. A. Bejan, *Advanced Engineering Thermodynamics*, 4th ed, Wiley, Hoboken, 2016.

9. A. Bejan, *Convection Heat Transfer*, 4th ed., Wiley, Hoboken, 2016.

10. A. Bejan and J. H. Marden, *Unifying constructal theory for scale effects in running, swimming and flying,* Journal of Experimental Biology, Vol. 209, 2006, pp. 238-248.

11. A. Bejan and J. H. Marden, *The Constructal unification of biological and geophysical design*, Physics of Life Reviews, Vol. 6, 2009, pp. 85-102.

12. A. Bejan, U. Gunes, J. D. Charles and B. Sahin, *The fastest animals and vehicles are neither the biggest nor the fastest over lifetime*, Scientific Reports, Vol. 8, 2018, article 12925.