Stress, our hated guard
Or how theoretical physics could explain the phenomenon of life

In his new book – Generalized Lagrangian Approach and Behavior of Living Systems – Professor Uziel Sandler, Bioinformatics Department Chair at Levr Academic Centre (JCT), explores how a generalised Lagrangian approach can help theoretical physics to describe the phenomenon of life. He demonstrates how the generalised Lagrangian allows Lagrangian dynamics to be used to describe the behaviour of living objects. Notably, he points out that these terms which make up the Lagrangians all have clear biological meanings and the proceeding results have a biological interpretation.

In his new book – Generalized Lagrangian Approach and Behavior of Living Systems – Professor Uziel Sandler explains how Lagrangian mechanics, where we are required to deduce the analytical forms of all forces that influence the system, the fundamental attribute of the Lagrangian approach is that the Lagrangian dynamics encapsulates the dynamics of the entire system of interest. LAGRANGIAN/HAMILTONIAN APPROACHES

Approximately half a century later, Sir William Hamilton demonstrated that a system’s trajectory that satisfies the Lagrangian equation also minimises a particular quantity that he referred to as an action. These Lagrangian/Hamiltonian approaches have generated significant success in theoretical physics, both in the description and understanding of the behaviour of non-living physical systems. Hamilton’s principle, also known as the principle of least action, can be employed to derive the Lagrange equation. This has been applied to many areas of fundamental theoretical physics including quantum mechanics and the theory of relativity.

LAGRANGIAN LIMITATIONS

Unfortunately, while Lagrangian equations were successfully applied to non-living physical systems, the Lagrangian, in its original form, is limited in that it cannot be applied to living systems. The Lagrangian/Hamiltonian dynamics and the principle of least action of time-independent Lagrangians lead to time-reversible equations of motion and to energy conservation, which cannot be true for living objects.

AN UNEXPECTED GENERALISATION

In his book, Professor Sandler explains how revisiting a lost opportunity that was not considered in the development of contemporary physics leads to a natural, but somewhat unexpected, generalisation of the Lagrangian function (referred to as S-Lagrangian), so Lagrangian equations lose their time-reversibility and conservation of energy. Since in the reference presented in the book, the Lagrangian function and the generalised Lagrangian are not associated with specific properties of any particular system, these equations should be able to describe the behaviour of living beings as well. The author goes on to demonstrate how S-Lagrangian dynamics allow us to describe a wide spectrum of the behaviour of living systems.

THE MAJOR PARADOX

While the primary distinction between living and non-living things is commonly regarded to be the ability to produce offspring, when considering individual life and not the population, the fundamental difference is that living creatures actively counteract their degradation within a continuously changing environment. A rudimentary attribute of living organisms is their endeavour to minimise the likelihood of death, a trait that even exists in an individual cell.

AN INDICATOR OF THE LIKELIHOOD OF DEATH

Environmental conditions are unpredictable, and this makes it impossible to produce a suite of programmable responses for all possible situations. It seems that living systems possess a generic indicator of the likelihood of death, and they try to minimise its value. Professor Sandler found stress, defined by its discoverer Hans Selye as “the non-specific response of the body to any demand placed upon it”, to be the most appropriate indicator due to its association with an organism’s undesirable states. Just as the common physical Lagrangians depend on the generalised position coordinates and their velocities, the S-Lagrangian depends on the stress, its conjugated variable, which relates to quantum mechanics rather than to classical physics, and relevant parameters of a living system and their time-derivatives (which play the role of the system’s “coordinates” and “velocities”). This forms the biological basis for Professor Sandler’s physics of life.

In this book, Professor Sandler demonstrates how assigning stress as the indicator of interest facilitates the design of the S-Lagrangians for a diverse range of living systems. In living systems, stress is an analogy of the Hamiltonian Action that should be minimised. Further exploration revealed that even the lowest approximation of these S-Lagrangians enables a satisfactory description of a broad class of behaviours of living organisms. Example applications presented in the text range from simple chemotaxis to the relationship between homeostasis and drug addiction, and to the behaviour of human populations in an environment.

FUZZY LOGIC

The classical Two-Valued-Logic, where every proposition is either true or false, is not satisfactory to provide a means of modelling vagueness and lack of certainty (which is a common feature in the description of living systems). Therefore, it should be replaced by continuous Fuzzy Logic, which is similar to our innate logic. In Fuzzy Logic, the truth variable can take on any real number value between zero as false and one as true. Amazingly, such a replacement allows Professor Sandler to find direct relation between the causality principle and the principle of least action together with generalisation of the Lagrangian function. This has enabled him to deploy the powerful mathematical apparatus of theoretical physics to describe living objects.

In creating this work, Professor Sandler finds himself in a similar situation to that of approximately three centuries ago, when the discovery of the Lagrangian approach enabled the resolution of problems that seemed extremely complex when viewed from the standpoint of Newtonian mechanics. Having dealt with the underlying mathematical concepts in the early chapters, the author presents a variety of examples of the considered approach illustrating the biological application of this methodology.

STRAIGHT FOR LIFE – HOMEOSTASIS

The S-Lagrangian underpins Sandler’s dynamic theory of homeostasis. Homeostasis refers to the regulating processes deployed by biological systems to sustain their viability and stability while they adjust to a continuously changing external environment. If homeostasis is successful, a system’s life continues; if it is unsuccessful, the system faces disaster and death. A paradox of living organisms is their ability to use homeostatic protection to offset degradation or injury in a changing environment.

Although homeostasis involves numerous different biochemical and physiological processes, it embraces surprisingly analogous features and behaviours in all living systems. Such universal behaviour is not unique in nature and has been observed, for example, in critical behaviour of...
overdose in 2015, rising to more than 47,000 deaths in 2017, with many more suffering from the drugs’ side effects. Heroin and other opioids affect the same areas of the brain as naturally produced endorphins and result in the same physiological effects, such as reducing stress and relieving pain, imitating the natural action of homeostasis. There is a critical issue, however, with artificially administered drugs. Homeostasis precisely regulates the amount of endogenous morphine it produces whereas any amount of heroin opioid can be administered voluntarily in order to achieve a feeling of euphoria. Moreover, a large amount of heroin will over-compensate for stress. Since homeostasis works in both directions, it attempts to correct this over-compensation. So, every time heroin is administered, the endogenous morphine receptors become desensitised: an equal dose of heroin will no longer compensate for stress or induce euphoria and higher doses are required each time. This results in chronic, dose-escalating drug abuse, with the result that the endogenous morphine cannot compensate for stress, leading to withdrawal symptoms.

The author has extended the theory of homeostasis to demonstrate the dynamics of drug abuse. He adds the artificially administered drugs to the S-Lagrangian, which results in a decrease of stress. He also takes into account how the intrusion of this external stress reducer inhibits the natural homeostasis-protective mechanisms. His simulations include modelling the dynamics of a single administration of the drug to an injured organism where homeostasis repairs and stabilises the organism. Contrastingly, modelling the development of dose-escalating drug abuse demonstrates that drug abuse impairs homeostasis. Repeated administration of the drug results in an organism becoming vulnerable to injury and disease, leading to premature disability and death. This demonstrates that overdoing is not the sole cause of death due to drug addiction. So, the actual number of Americans who have died as a result of drug abuse must be much higher than was mentioned above.

The modelling of homeostasis revealed that if an organism is likely to die under high stress, it will consolidate all available resources in order to neutralise this threat. Surprisingly, simulations of voluntary, repeated suppression of stress by a non-specific external stress reducer confirmed that this leads to the development of addiction, because in a state of euphoria an organism subconsciously perceives that it is doing well since it has reduced the inner indicator of proximity to death (the stress). As a result, weak intellectual objections are disregarded in lieu of powerful emotional feelings. Addiction kills us by a “sweet” death. So, voluntary, repeated suppression of stress by an external stress reducer regardless of the primary source of the stress, could be more harmful than the stress itself.

**STRUGGLE FOR DOMINANCE IN SOCIAL GROUPS**

Hierarchical structures and dominance exist in most social groups of living things ranging from groups of cancer cells or neurons in the brain to human society. Commonly these hierarchies are attributed to competition for better resources and breeding, leading to antagonistic interactions between members of the group. Those that win most of the contests move higher within the group, while those that lose are dropped to the lower ranks.

However, the same dominance hierarchies still exist in friendly environments with abundant resources even though aggressive interactions are not present. Regardless of the disparities between species and their behaviours, dominance hierarchies are comparable among most social groups. This suggests that dominance hierarchies are the product of some common characteristics of the behaviour of living things.

The author demonstrates that the incentive for living beings to form hierarchical structures may result from their attempts to cope with stress, which results from disparity between the “real world” (actual states of the

FROM PROTECTOR TO ASSASSIN

Homeostasis protection involves the rapid reduction of stress followed by a more gradual repairing process. In humans, the swift decrease in stress results from the release of chemicals like endorphins, known as endogenous opioids, which are hastily produced in a natural response to severe injury and pain. However, inappropriate artificial replication of this emergency mechanism can have the opposite effect, inhibiting natural homeostasis with detrimental results.

In the late 1890s, the company now known as Bayer Pharmaceuticals synthesised an artificial opiate, diamorphine, which was aggressively marketed. This new drug became known as heroin (derived from ‘heroic’) marketed. This new drug became known as diamorphine, which was aggressively marketed. This new drug became known as Bayer-Pharmaceutical

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Applying S-Lagrangian dynamics enables the main features of hierarchy formation and dominance to be described. After performing a number of simulations, the theory predicts three levels of dominance and hierarchy formation. The first level occurs if a group is made up of individuals who take noticeably different lengths of time to cope with stress: the individual with the fastest coping time becomes dominant and assumes leadership of the group. The second level occurs when the group members take similar lengths of time to cope with stress, then the member with the largest stress-threshold assumes leadership of the group. The third level occurs if the individuals within the group take similar times to cope with stress and have similar stress-thresholds. In this case, the individual with the highest tolerance to the difference between the group members’ actual states and their desirable behaviour stereotypes becomes dominant. (Figures 2.1–2.4, previous page)

While the first and second levels have a physiological nature, the third level depends on the emotional spirit and training of group members. The first level creates a despotic hierarchy, where an individual member is the dominant leader of the group and all the other members are submissive servants. The other levels are more likely to create linear hierarchies with each individual member dominating those individuals of a lower ranking. It should be emphasised that this hierarchy formation is pure “dynamical effect”, because it appears as a consequence of the equations of evolution, while initially all a group’s members were assumed to have an equal status.

The study detailed in this book connects the commonly suggested mechanisms of dominance formation to the inner physiological features of living species and correlates with the frequently used winner-loser hypothesis of dominance behaviour.

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Behind the Research

Professor Uziel Sandler

Research Objectives

Professor Sandler explores how a Lagrangian approach can be used to help physics describe living systems.

References


Personal Response

What initially sparked your interest in physics?
The blessed memory of my mother, the brilliant physicist who instilled in me a proclivity for science and, in particular, for physics.

Why do you think that the 'lost opportunity' was not considered until your discovery of the Generalized Lagrangian?

What prompted you to extend the theory of Lagrangian to living things?
The Lagrangian approach was extended to living things in order to describe the behaviour of living beings.

What is the impact of your work on the future of the environment?

What has been the most rewarding outcome of your research?

What is the most significant aspect of your work global warming in particular and climate change in general?

Which academic fields do you think will benefit most from your work?

What can you predict about the future of physics?

What do you think is the future of physics?

What do you think is the future of the world?

What is the most rewarding outcome of your research?

Only the future can answer this question.