



EVOLUTION 'ON PURPOSE': TELEONOMY IN LIVING SYSTEMS

MONDAY 28TH AND TUESDAY 29TH JUNE 2021
2 DAY ONLINE INTERNATIONAL MEETING ORGANISED BY
THE LINNEAN SOCIETY OF LONDON

Living systems exhibit an internal teleology, the full implications of which have not been explored. This meeting will address various aspects of this phenomenon, including its scope and meaning, and its many forms and facets.

Although it is now widely accepted that living systems exhibit an internal teleology, or *teleonomy*, the full implications of this distinctive biological property have yet to be explored. This online conference will seek to address various aspects of this important phenomenon, including the origins and history of the teleonomy concept, its scope and meaning, and its many forms and facets. Possible topics may include: an historical review of teleological thinking; teleology (and entelechy) versus teleonomy in evolutionary theory; the nature of teleonomy (who/what is in control, and how?); agency and teleonomy; semiotics and teleonomy; modeling teleonomic processes; teleonomy in the genome, in epigenesis, in physiology, and in behaviour; teleonomy and natural selection; teleonomy in human evolution; and, especially significant, how teleonomy has influenced the evolutionary process.

PROGRAMME

June 28, 12-4 PM GMT (1-5 BST): 8 half hour presentations
June 28, 5:30-7:30 PM GMT (6:30-8:30 BST): 4 half hour presentations

June 29, 12-4 PM GMT (1-5 BST): 8 half hour presentations
June 29, 5:30-7:30 PM GMT (6:30-8:30 BST):
1 hour, pre-arranged comments, 1 hour, open discussion

MONDAY JUNE 28

- 12.00 (GMT) Welcome by the **President of the Linnean Society of London**
- 12.05–12.30 Peter Corning FLS (ISCS, Seattle) | **Teleonomy in Evolution: “The Ghost in the Machine”**
- 12.30–13.00 J. Arvid Ågren (Harvard) | **The Paradox of the Organism Revisited**
- 13.00–13.30 Bernard Crespi (Simon Fraser) | **Three Laws of Teleonometrics**
- 13.30–14.00 Dominik Deffner | (MPIEA, Leipzig | **Constructing 'On Purpose': How Niche Construction Affects Natural Selection**
- 14.00–14.30 Simon Gilroy (Wisconsin) and Anthony Trewavas, FRS (Edinburgh) | **Signal Transduction, Decision Making, and Agency in Plant Systems**
- 14.30–15.00 Nathalie Gontier (Lisbon) | **Teleonomy as a Problem of Causation, and Causation as a Problem of Hierarchy and Time**
- 15.00–15.30 Francis Heylighen (Vrije Universiteit Brussels) | **The Origin of Goal-Directed Organization: Towards a Mathematical Model**
- 15.30–16.00 Eva Jablonka (Tel Aviv, and LSE, London) | **From Teleonomy to Teleology: Evolutionary Considerations**
- 16.00–17.30 90 MINUTE BREAK
- 17.30–18.00 Stuart Kauffman and Andrea Roli (ISB, Seattle) | **What is Consciousness? Artificial Intelligence, Real Intelligence, Quantum Mind, and Qualia**
- 18.00–18.30 Eugene V. Koonin, Vitaly Vanchurin & Yuri I. Wolf (NCBI, Bethesda) and Mikhail I. Katsnelson (Radboud) | **A Theory of Universal Evolution as a Learning Process**
- 18.30–19.00 Kalevi Kull (Tartu) | **How do Organisms Choose?**

19.00–19.30 Dan McShea and Gunnar Babcock (Duke) | **An Externalist Teleology**

19.30 CLOSE OF FIRST DAY

TUESDAY JUNE 29

12.00 (GMT) START OF SECOND DAY

12.00–12.30 Armin P. Moczek (Indiana) | **When the End Modifies its Means: The Origins of Novelty and the Evolution of Innovation**

12.30–13.00 Stuart A. Newman (New York Medical College) | **Cellular Agency and Mesoscale Physics in the Evolution of Multicellular Development**

13.00–13.30 Daniel J. Nicholson (George Mason) | **Does the Concept of Teleonomy Solve the Problem of Organismic Purposiveness?**

13.30–14.00 Raymond Noble (London) and Denis Noble (Oxford) | **Physiology and Telos: Is Teleology a Sin?**

14.00–14.30 Samir Okasha (Bristol) | **Teleonomy, Agency, and Unity of Purpose**

14.30–15.00 James A. Shapiro (Chicago) | **Teleonomy and Genome Change**

15.00–15.30 Stephen Talbott (The Nature Institute, Ghent NY) | **Toward a Thought-full Teleology – Beyond the Hollow Organism**

15.30–16.00 Denis Walsh (Toronto) | **Teleophobia**

16.00–17.30 90 MINUTE BREAK

17.30–18.30 **pre-arranged comments**

18.30–19.30 **open discussion**

19.30 CLOSE OF MEETING

Organisers: **Peter Corning** FLS (ISCS, Seattle) and **Dick Vane-Wright** FLS (NHM London)

Programme Committee: **Peter Corning** FLS, **Eva Jablonka**, **Stuart Kauffman**, **Denis Noble**, **Samir Okasha**, **James Shapiro**, **Dick Vane-Wright** FLS and **Denis Walsh**

ABSTRACTS & BIOGRAPHIES

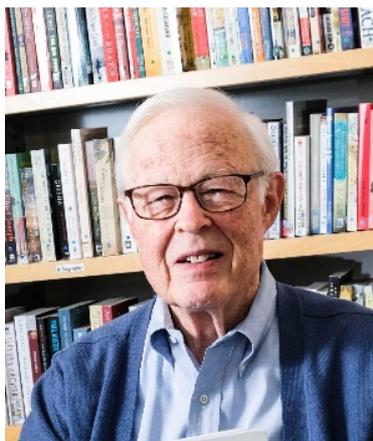
TELEONOMY IN EVOLUTION: “THE GHOST IN THE MACHINE”

Natural selection is not a mechanism; it’s a consequential happening.
Teleonomy is an outcome, and a cause.

Peter A. Corning | Institute for the Study of Complex Systems, Seattle WA, USA

Although it is now widely accepted that living systems exhibit an evolved purposiveness, or *teleonomy*, the theoretical implications of this distinctive biological property have yet to be fully explored. Here I will briefly discuss the origins and history of the concept, along with its scope and meaning and some of its many forms and facets. I will also attempt to clarify the often-misunderstood concept of natural selection. However, I will focus especially on the causal role of purposeful behaviours in shaping natural selection, and on how teleonomy and functional synergy (combined or co-operative effects of various kinds) have together influenced the rise of biological complexity in the natural world. An important example is the evolution of humankind, which the zoologist Jonathan Kingdon, in his book-length treatment of the subject, characterized as the “Self-Made Man.”

Registered attendees can address questions about this talk to: pacorning@complexsystems.org



Peter A. Corning is currently the Director of the Institute for the Study of Complex Systems in Seattle, Washington. He holds a B.A. from Brown University, served as a naval aviator, was a science writer at *Newsweek* Magazine, obtained an interdisciplinary Ph.D. from New York University, won an NIMH post-doctoral fellowship at the Institute for Behavioral Genetics (University of Colorado), and taught for many years in the Human Biology Program at Stanford University, along with holding a research appointment in Stanford’s Behavior Genetics Laboratory. He is a past president of the International Society for the Systems Sciences and an officer of the Bioeconomics Society. Areas of research include biological evolution, complex systems, systems theory, and cybernetic information theory. In addition to some 200 professional papers and articles, he has to

date published seven books, including, most recently, *Synergistic Selection: How Cooperation Has Shaped Evolution and the Rise of Humankind* (World Scientific, 2018).

THE PARADOX OF THE ORGANISM REVISITED

J. Arvid Ågren | Department of Organismic and Evolutionary Biology, Harvard University, USA

When biologists talk about purpose it is usually in reference to organisms: organisms that struggle to survive and organisms that compete to reproduce. Assigning agency to organisms relies on an implicit assumption of a within-body unity of purpose. That is, that all parts of the organism are working together for the same goal: to enhance the (inclusive) fitness of the individual organism. However, not all parts of organisms do work together. Instead, the organism is constantly threatened from within by other evolutionary agents, such as cancer cells and selfish genetic elements, genes able to promote their own propagation at the expense of organismal fitness. We can therefore talk about a paradox of the organism, a term first coined by Richard Dawkins thirty years ago. Despite the opportunity for agents like selfish genetic elements and cancer cells to erode the organism from within and shift agency to a lower level of organization, they usually do not. But why not? And how would we even measure it if they did? In this talk, I will explore the paradox of the organism and investigate its implications for notions of teleonomy and evolutionary agency. The paradox of the organism forces us to think about what individual organisms are to begin with, and how they achieve their unity of purpose. By moving beyond the traditional organism-centered account of teleonomy, we can begin to develop a new, more nuanced concept that takes within-organism conflict seriously.

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J. Arvid Ågren is an evolutionary biologist, currently holding a Wenner-Gren Fellowship at the Department of Organismic and Evolutionary Biology at Harvard University. His research focuses on genomic conflicts and he has published widely on their biology and implications for evolutionary theory. He is the author of the forthcoming book *The Gene's-Eye View of Evolution* (Oxford University Press). Prior to joining Harvard, he received his PhD at the University of Toronto and was a postdoctoral associate at Cornell University.

THREE LAWS OF TELEONOMETRICS

Bernard Crespi | Simon Fraser University, British Columbia, Canada

I define teleonometrics as the theoretical and empirical study of teleonomy. I propose three laws for teleonometrics. The first law describes the hierarchical organization of teleonomic functions across biological levels from genes to individuals. Under this law, the number of goal-directed functions increases from individuals (one goal, maximizing inclusive fitness) to intermediate levels, to genes and alleles (many time, space and context-dependent goals, depending upon degrees and patterns of pleiotropy). The second law describes the operation of teleonomic functions under tradeoffs and coadaptations, which are universal in biological systems. By this law, the functions of an allele, gene or trait are described by patterns of antagonistic (trading off) and agonistic (compatible and coadapted) pleiotropy. Antagonistic pleiotropy constrains adaptation and global optimization, but tradeoffs can be broken by various mechanisms including divisions of labour. Application of this law raises the questions of what a gene or allele is actually 'for', and why genes and alleles vary in their patterns, or 'shapes', of pleiotropy. The third law of teleonometrics is that the major transitions in evolution are driven by the origins of novel, emergent goals associated with changes in functionality. Teleonometrics, and its laws, can be studied empirically using genetic and phenomic data. I illustrate such approaches using data on pleiotropy of intelligence with autism risk and with schizophrenia risk, and data on the genetic basis of endometriosis and polycystic ovary syndrome.

Registered attendees can address questions about this talk to: crespi@sfu.ca



Bernard Crespi took his undergraduate degree at the University of Chicago, and did his PhD at the University of Michigan, Ann Arbor, with Williams D. Hamilton and Richard D. Alexander. His thesis work was on the behavioral ecology of small, fungus-feeding insects. He conducted post-doctoral studies at the University of New South Wales (with Ross Crozier), at Cornell (with Rick Harrison) and at Oxford (with W. D. Hamilton), and started a tenure track position at Simon Fraser University in Vancouver, British Columbia, Canada in 1992, where he is now a Professor. His work has focused on, in loose chronological order, insect behavior and sex ratios, social evolution and eusociality, human evolution, genomic conflicts, speciation, placentation, cancer, autism and schizophrenia, and female reproductive disorders. He currently holds a Canada Research Chair in Evolutionary Genetics and Psychology, and he is a member of the Royal Society of Canada.

CONSTRUCTING 'ON PURPOSE': HOW NICHE CONSTRUCTION AFFECTS NATURAL SELECTION

Dominik Deffner | Max Planck Institute for Evolutionary Anthropology, Leipzig

Organisms actively modify and choose components of their environments. Theory suggests such 'niche construction' might affect ecological processes, alter selection pressures and contribute to the transgenerational transmission of information. Importantly, if that environmental regulation by organisms is systematic and directional, it can potentially impose biases on selection, and thereby influence evolutionary outcomes. Here we explore how the variability of natural selection is affected by organisms that regulate the experienced environment through their activities (whether by constructing components of their local environments, such as nests, burrows, or pupal cases, or by choosing suitable resources). Specifically, we test the predictions that organism-constructed sources of selection that buffer environmental variation will result in (i) reduced variation in selection gradients, including reduced variation between (a) years (temporal variation) and (b) locations (spatial variation), and (ii) weaker directional selection relative to non-constructed sources. Using compiled data sets of 1,045 temporally replicated selection gradients, 257 spatially replicated selection gradients, and a pooled data set of 1,230 selection gradients, we find compelling evidence for reduced temporal variation and weaker selection in response to constructed compared to non-constructed sources of selection and some evidence for reduced spatial variation in selection. These findings, which remained robust to alternative data sets, taxa, analytical methods, definitions of constructed/non-constructed, and other tests of reliability, suggest that organism-manufactured or chosen components of environments may have qualitatively different properties from other environmental features.

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Dominik Deffner is an evolutionary and computational behavioural scientist with parallel bachelor degrees in psychology (BSc) and cultural anthropology (BA) at Marburg University in Germany. After a Masters with Kevin Laland at the University of St Andrews, Scotland, he pursued a PhD in cultural evolution with Richard McElreath at the Max Planck Institute for Evolutionary Anthropology, in Leipzig, Germany. His research is broadly focused on niche construction, social learning and the evolutionary mechanisms underlying human cultural adaptation. He mostly uses behavioural group experiments, computational and statistical modeling as well as formal mathematical theory to better understand the unique adaptability of our species.

SIGNAL TRANSDUCTION, DECISION MAKING, AND AGENCY IN PLANT SYSTEMS

Simon Gilroy | University of Wisconsin, USA

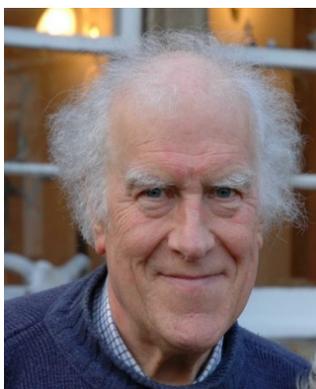
Anthony Trewavas, FRS | University of Edinburgh, UK

Plants like all organisms are aware of their environment and change behaviour that is designed to intelligently improve survival. Agency describes the ability of individual plants to identify, negotiate and pursue the goals of survival and reproduction. The repertoire of available behaviours to support the requirements of agency is substantial but different to those in animals. Because these are accomplished in a very different time frame to us as animals, they are often underestimated and not noted. Current plant mechanisms whereby behaviour is changed involve electrical changes, intracellular calcium and ROS transduction and genomic alterations. Plants learn and remember but the processes are again different to those in the higher animals. Based on the ratio of atmospheric gases, plants form more than 99% of life on this planet. The plant lifestyle can then be regarded as highly successful and much more productive than those of animals that opted at the single cell stage to remain hunting for food.

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Simon Gilroy received his Ph.D. at the University of Edinburgh in Scotland and then moved to the University of California at Berkeley, The Pennsylvania State University and finally to the University of Wisconsin-Madison where he has been a professor in the Department of Botany since 2007. Dr. Gilroy uses a combination of molecular techniques, genetic analyses and imaging to follow how plants sense and respond to environmental cues. His research group is currently studying plant reactions to stresses ranging from herbivory and touch to flooding and changes in gravity. He is pursuing these projects in settings that range from his laboratory at UW-Madison to experiments on the International Space Station.



Tony Trewavas is an emeritus professor at the University of Edinburgh, Scotland. He is also a fellow of the Royal Society of London, a fellow of the Royal Society Edinburgh, and of Academia Europea. He has published some 300 papers and three books, the most recent being *Plant Behaviour and Intelligence* (2014). His primary interest is in the nature and characteristics of plant behaviour and its construction and regulation by plant cytosolic calcium, which seems to mediate many of the enormous number of signals that alter plant behaviour.

TELEONOMY AS A PROBLEM OF CAUSATION, AND CAUSATION AS A PROBLEM OF HIERARCHY AND TIME

Nathalie Gontier | University of Lisbon, Portugal

I will demonstrate that any and all theorizing on teleonomy is dependent upon theorizing on 1) the nature of causation, and 2) the nature of time. Causation theories are generally framed from within evolutionary hierarchy theories, but that causation theories also depend upon notions of time is often ignored. I will therefore investigate how different causal evolution theories not only associate with different ontological hierarchies, but also with different time theories, and how this impacts theorizing on teleonomy. Upward causation theories associate with linear hierarchies that bring forth linear notions of time, and in biology, they underlie the causal reasoning of the Neo-Darwinian Synthesis. Eco-Evo-Devo schools in addition recognize the importance of downward causation and such receives resistance from the standard view because downward causation is sometimes understood as backward causation, and that is considered impossible by adherents of a linear time model. Instead I will argue that downward causation works with a spatial or presential time notion. In addition, I will explain how hybridization, lateral gene transfer, infective heredity, symbiosis and symbiogenesis require us to recognize the existence of reticulate causation that occurs between distinct and interacting ontological hierarchies, and I will demonstrate how these phenomena need to be conceptualized as occurring in both space and time or spacetime. And finally, and by drawing on examples from spontaneous generation debates, I will look into Driesch' notion of "individualizing causality" and what Corning calls "internal teleology" and investigate what kinds of hierarchical, causal, and timely views such notions imply.

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Nathalie Gontier is a researcher for the Faculty of Science of the University of Lisbon, sponsored by the Portuguese Foundation for Science and Technology under law 57/2016, and she is an Integrated Member of the Center for Philosophy of Sciences. Since 2012, she is the director of [AppEEL – The Applied Evolutionary Epistemology Lab](#) that was founded with the support of the John Templeton Foundation. She has a background in both Philosophy and Comparative Science of Cultures (Cultural Anthropology), and she holds a PhD in Philosophy of Science. She is the Editor-in-Chief of the Springer Book Series [Interdisciplinary Evolution Research](#), Associate editor for [Evolutionary Biology](#), Advisory Editorial Board Member for [Theoria et Historia Scientiarum](#), and [Empedocles: European Journal for the Philosophy of Communication](#), and Review Editor for [Frontiers in Psychology/Theoretical and Philosophical Psychology](#). She sits on the permanent board of the [Protolang](#) Conference Series, is a Member of the [Third Way of Evolution](#), and a collaborator for the [Astra Project](#). Her personal website can be found at <https://lisboa.academia.edu/NathalieGontier>.

THE ORIGIN OF GOAL-DIRECTED ORGANIZATION: TOWARDS A MATHEMATICAL MODEL

Francis Heylighen | Center Leo Apostel, Vrije Universiteit Brussels, Belgium

The notion of goal-directedness or teleology has long been considered to be outside the realm of science. Physical science assumes that effects are fully determined by their causes, which lie in the past. Therefore, it does not seem possible for a goal, which lies in the future, to affect phenomena here and now. Yet, living systems are *teleonomic*: they behave as if they are striving to achieve some as yet distant goal state. That means that whatever their initial state (cause) they will act so as to reach this particular end state, thus making it appear as if it is this end state and not the initial state that determines their behavior.

A solution to this paradox, first suggested in a classic paper entitled “Behavior, Purpose and Teleology” (Rosenblueth, Wiener, & Bigelow, 1943), was proposed by the theory of *cybernetics*. Cybernetics introduced the notion of *circular causality* to explain how an end state can affect an initial state via the mechanism of feedback. Applied to organisms, circular causation inspired what is perhaps the most general definition of life: *autopoiesis*. An autopoietic system is a network of processes that continuously (re)produces its own components, so as to ensure that its organization survives both the wear and tear of entropy and any external disturbances threatening its integrity. Its implicit goal is self-maintenance. Thus, it exemplifies a structure with *emergent purpose*: its components and processes are merely simple causal mechanisms; yet together they form an autonomous “agent” or “self”, i.e., an organizationally closed whole that will act so as to ensure its continued existence.

While autopoietic systems are goal-directed, the theory does not explain how such living systems could have evolved out of abiotic systems that lacked this feature. From the proposed scenarios for the origin of life, the one that comes closest to the circular causality demanded by autopoiesis is the self-organization of an *autocatalytic cycle*. However, such cycles tend to be intrinsically unstable and prone to an “*error catastrophe*”: if at some stage a wrong catalyst is introduced, this error cannot be corrected, and is likely to snowball into errors producing further errors, until the cycle completely breaks down.

Inspired by the theory of autopoiesis, Peter Dittlich has recently proposed a generalization of the notion of autocatalytic set, which he termed a *chemical organization*. Like an autopoietic system, such an organization produces its own components, thus constituting itself as an autonomous unit. But unlike the rather

obscurely formulated notion of autopoiesis, a chemical organization has a precise mathematical structure that can be investigated analytically and computationally.

The elements of the formalism are *molecules* $\{a, b, c, \dots\}$ and *reactions* which have the form: $a + b + \dots \rightarrow e + f + \dots$. The reactions represent processes that transform combinations of molecules into new combinations of molecules. Reactions can be catalyzed by specific molecules, but in general are not. "Molecules" do not have to be actual chemical reactants. They can represent any resources that react with other resources to produce further resources. The reaction system formalism of Chemical Organization Theory makes abstraction of the physical or biochemical nature of the resources so as to better understand the functional relationships between reactions

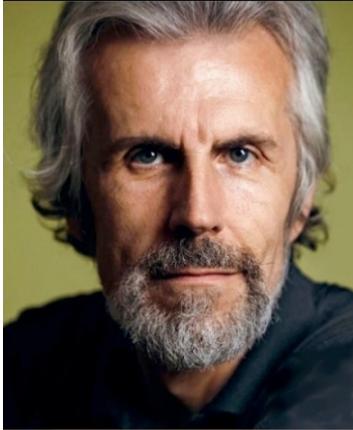
A set of molecules and its corresponding reactions forms an organization when it is *closed* and *self-maintaining*. *Closed* means that no molecules are produced by the reactions that were not in the initial set. *Self-maintaining* means that all molecules consumed by some reactions are produced again by other reactions so that their total concentration does not diminish. Thus, all resources constituting the organization are perpetually recycled.

To be truly goal-directed, organizations should not just be able to maintain themselves in ideal circumstances; they should also be able to return to this state of self-maintenance when pushed away from this desired state by external challenges. Such capacity for a system to recover efficiently from stressful circumstances is called *resilience*. That is necessary to make them impervious to the error catastrophe and other sources of instability that threaten emerging goal-directed systems.

Our team at the Center Leo Apostel has started an ambitious project, funded by the Templeton Foundation in its program on "The Science of Purpose", to computationally explore, mathematically model and conceptualize the self-organization and evolution of such goal-directed organizations. We will apply the resulting insights to clarify the origin of life, as well as evolutionary transitions, in which a number of initially independent components, such as cells, develop a collective organization, such as a multicellular organism, characterized by a common purpose.

Registered attendees can address questions about this talk to: francis.heylighen@vub.be

Francis Heylighen is a research professor and director of the Center Leo Apostel for transdisciplinary studies at the Vrije Universiteit Brussel. He received his MSc. in mathematical physics in 1982 and defended his PhD. in 1987, on the cognitive processes and structures underlying physical theories. He then shifted his research to the self-organization and evolution of complex, cognitive systems, which he approaches from a cybernetic perspective, with an emphasis on their distributed intelligence. He teaches at the VUB's philosophy department on complexity, evolution, mind, brain, and the social implications of technology. Francis Heylighen has authored over 200 scientific publications in a wide



variety of disciplines, with over 11000 citations. He is a Fellow of the World Academy of Art and Science, recipient of the 2015 Outstanding Technology Award from the Web Intelligence Consortium, and his biography is listed in Who's Who in the World, Wikipedia, and other international directories.

FROM TELEONOMY TO TELEOLOGY: EVOLUTIONARY CONSIDERATIONS

Eva Jablonka | The Cohn Institute for the History and Philosophy of Science and Ideas, Tel Aviv University, Israel; Centre for Philosophy of Natural and Social Science, London School of Economics and Political Science, UK

Goal-directed behavior that does not depend on conscious will or preconceived design is referred to as teleonomic behavior. The evaluative systems that underlie teleonomic behavior in living organisms sense deviations from homeostasis and employ mechanisms of adaptive plasticity to restore, sustain and boost survival and reproduction. By virtue of their sustainability, all living organisms have an intrinsic teleonomic organization, but some show, in addition, teleological behavior that supports and overlays it – goal-directed behavior that is driven by subjectively felt passions and aversions. Such organisms, which can be said to act because they want or do not want to reach some goal, evaluate sensory inputs and their own actions through felt emotions and drives. During further evolution, another layer of teleology, attaining goals guided by imagination, was added to passion-driven teleological behavior, and in humans, goal-directed behavior can be also driven by rational design and abstract values, which involve symbolic systems of representation and communication. Here I discuss the evolutionary origins and effects of teleological behavior. I argue that the evolution of teleological behavior was driven by the evolution of learning and that many patterns of evolution since the Cambrian explosion can be explained only if evolution through conscious choice is assumed.

Registered attendees can address questions about this talk to: jablonka@tauex.tau.ac.il

Eva Jablonka is a retired professor in the Cohn Institute for the History and Philosophy of Science and Ideas, Tel-Aviv, a member of the Sagol School of Neuroscience, Tel-Aviv, and a Research Associate in the CPNSS (LSE, London University). Her main interests are the understanding of evolution, especially evolution that is driven by non-genetic hereditary variations, and the evolution of nervous systems and



consciousness. Her books in English include: *Epigenetic Inheritance and Evolution* (OUP with Marion Lamb), *Animal Traditions* (CUP with Eytan Avital), *Evolution in 4 Dimensions* (MIT Press with Marion Lamb), *The Evolution of the Sensitive Soul* (MIT Press with Simona Ginsburg), *Inheritance Systems and the Extended Evolutionary Synthesis* (CUP, with Marion Lamb), and *Picturing the Mind: Consciousness through the Lens of Evolution* (in press with MIT Press, with Anna Zeligowski and Simona Ginsburg).

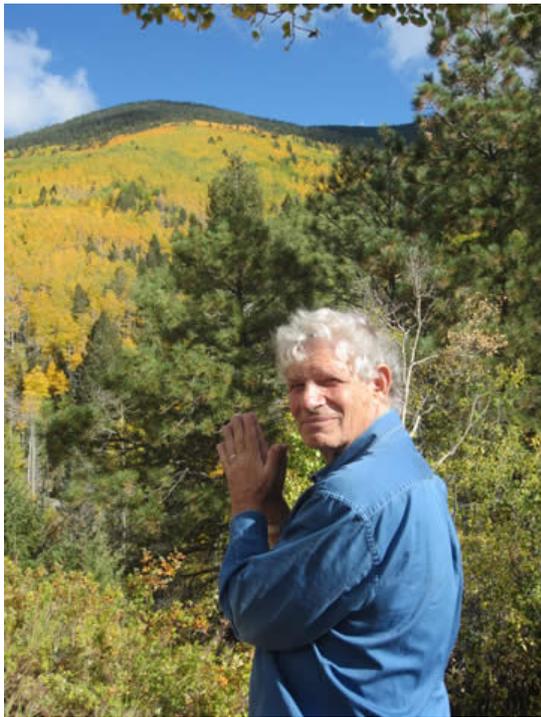
WHAT IS CONSCIOUSNESS? ARTIFICIAL INTELLIGENCE, REAL INTELLIGENCE, QUANTUM MIND, AND QUALIA

Stuart Kauffman and Andrea Roli | The Institute for Systems Biology, Seattle, WA, USA

We approach the question, “What is Consciousness?” in a new way, not as Descartes’ “systematic doubt”, but as how organisms find their way in their world. Finding one’s way involves finding possible uses of features of the world that might be beneficial or avoiding those that might be harmful. “Possible uses of X to accomplish Y” are “Affordances”. The number of uses of X is indefinite, the different uses are unordered and are not deducible from one another. All biological adaptations are either affordances seized by heritable variation and selection or, far faster, by the organism acting in its world finding uses of X to accomplish Y. Based on this, we reach rather astonishing conclusions: 1) Strong AI is not possible. Universal Turing machines cannot “find” novel affordances. 2) Brain-mind is not purely classical physics for no classical physics system can be an analogue computer whose dynamical behavior can be isomorphic to “possible uses”. 3) Brain mind must be partly quantum – supported by increasing evidence at 6.0 sigma to 7.3 Sigma. 4) Based on Heisenberg System’s interpretation of the quantum state as “Potentia” converted to “Actuals” by Measurement, a natural hypothesis is that mind actualizes Potentia. This is supported at 5.2 Sigma. Then Mind’s actualization of entangled brain-mind-world states are experienced as qualia and allow “seeing” or “perceiving” of uses of X to accomplish Y. We can and do jury-rig. Computers cannot. 5) Beyond familiar quantum computers, we consider Trans-Turing-Systems.

Key Words: Affordances, universal Turing machines, analog computers, classical physics, quantum mechanics, strong AI, potentia, actuals, classical neurodynamics, quantum computing, dynamical criticality, soft matter, trans-Turing-systems.

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Stuart Alan Kauffman, M.D., is an American theoretical biologist and complex systems researcher who studies the origin of life on Earth. He graduated from Dartmouth in 1960, was awarded the BA (Hons) by Oxford University (where he was a Marshall Scholar) in 1963 and completed a medical degree (MD) at the University of California, San Francisco in 1968. After completing his residency, he moved into developmental genetics of the fruit fly, holding appointments first at the University of Chicago 1969-1973, National Cancer Institute 1973-1975, then at the University of Pennsylvania from 1975 to 1995, where he served as Professor of Biochemistry and Biophysics. Kauffman held a MacArthur Fellowship from 1987-1992. He also holds an Honorary Degree in Science from the University of Louvain; and was awarded a Gold Medal of the Accademia Lincea in Rome. Dr. Kauffman rose to prominence through his association with the Santa Fe Institute (a non-profit research institute dedicated to the study of complex systems), where he was faculty in residence from 1986 to 1997.

Dr. Kauffman is best known for arguing that the complexity of biological systems and organisms might result as much from self-organization and far-from-equilibrium dynamics as from Darwinian natural selection, as well as for applying models of Boolean networks to simplified genetic circuits. His hypotheses stating that cell types are attractors of such networks, and that genetic regulatory networks are "critical" have found experimental support. Dr. Kauffman, with M. Ballivet, held the founding broad biotechnology patents, filed 1985, in combinatorial chemistry and applied molecular evolution, now a multibillion global industry. He also proposed the self-organized emergence of collectively autocatalytic sets of polymers, specifically co-evolving peptides and RNA, for the origin of molecular reproduction. He has also proposed the "TAP" equation for cumulative technological evolution. More recently, Dr. Kauffman and Andrea Roli have published "The World Is Not A Theorem", (2021), maintaining that the evolving biosphere is a propagating construction, not an entailed deduction, and that no mathematics based on set theory can be used with respect to the diachronic emergence of adaptations in evolution. Dr. Kauffman has published over 350 articles and 6 books: *The Origins of Order* (1993), *At Home in the Universe* (1995), *Investigations* (2000), *Reinventing the Sacred* (2008), *Humanity in a Creative Universe* (2016) and *A World Beyond Physics* (2019).

A THEORY OF UNIVERSAL EVOLUTION AS A LEARNING PROCESS

Eugene V. Koonin | National Center for Biotechnology Information, National Library of Medicine, Bethesda, MD, USA

Vitaly Vanchurin | National Center for Biotechnology Information, National Library of Medicine, Bethesda, MD, USA

Yuri I. Wolf | National Center for Biotechnology Information, National Library of Medicine, Bethesda, MD, USA

Mikhail I. Katsnelson | Radboud University, Institute for Molecules and Materials, Nijmegen, Netherlands

We present a model based on the theory of learning, in which the evolution of entire Universe is described as a learning process that minimizes the system's loss function and involves selection for persistence. We show that learning systems evolve multiple temporal scales, which encompass trainable variables changing at different rates and that such scale separation yields complex structures. Under our model, evolution of life is the most complex manifestation of the universal evolutionary process that requires at least three scales of variables corresponding to the environment (fast), phenotype (slower) and genotype (the slowest). The slowest-changing variables evolve to be digitized and comprise both the "instruction set" and the long-term memory for training the faster variables, which in turn provide feedback to the slowest variables in the form of differential reproduction. Scale separation is necessary but not sufficient for the origin of life, which additionally requires the instruction set to attain a threshold level of complexity with a large number of degrees of freedom, resulting in a glass-like fitness landscape with numerous local minima. On such a landscape, the learning process resolves frustrations caused by competition between interactions on different scales, producing the organizational complexity that is unique to life and necessary for long-term sustained evolution. The key intrinsic features of living organisms, namely, replication of the carriers of the slowest-changing variables (genomes), multilevel selection, appearance and persistence of parasites, and programmed death naturally emerge in this model.

Registered attendees can address questions about this talk to: koonin@ncbi.nlm.nih.gov

Eugene V. Koonin holds a BSc, from Moscow State University, Russia, a PhD, from Moscow State University, Russia, was a Postdoctoral Fellow, Institute of Poliomyelitis, Russian Academy of Medical Sciences, a Senior Researcher; Laboratory Chief, Institute of Microbiology of the Russian Academy of Sciences; Visiting Scientist, National Center for Biotechnology Information, NIH, Bethesda, MD.. His



present position is Leader of the Evolutionary Genomics Group, NIH Distinguished Investigator. His honors and awards: Fellow, AAM; Fellow, American Academy of Arts and Sciences; Member, National Academy of Sciences of the USA; Foreign Associate, European Molecular Biology Organization, Russian Academy of Sciences; *Doctor Honoris Causa*, Universite Aix-Marseille (France), Wageningen University (Netherlands); National Library of Medicine Board of Regents Award; NIH Director's Award; Benjamin Franklin Award. His professional activities include: Editor-in-Chief, *Biology Direct*; Associate Editor: *Genome Biology and Evolution*. Editorial Boards: *Nucleic Acids Research*, *BMC Biology*, *RNA Biology*. His principal research interests include: computational and theoretical research in several major directions that are broadly linked by the theme of genome evolution; in particular, co-evolution of cellular life forms with genetic parasites, such as viruses, transposons and plasmids; evolution and origin of viruses; evolution of cancer.

HOW DO ORGANISMS CHOOSE?

Kalevi Kull | University of Tartu, Estonia

One of Karl Popper's writings was entitled as "A world without natural selection but with problem solving". The 'problem solving', if not just a metaphor for certain deterministic process, assumes indeterminacy, motivation and choice, referring to some fundamental freedom in an organisms' behaviour. Accordingly, the mechanism of problem solving and the scope of its existence in living beings deserves a closer look in biology.

A problem, or a problem situation, in the general sense, is a situation in which the behaviour has to be indeterminate, and a choice-making has to be possible. This occurs if coupled functional systems face mutual incompatibility. For instance, perceptions from two sense organs order the opposite actions of the same effector. Or, a perception orders two effectors that lead to opposite actions. This is a situation in which organism's behaviour is not fully determined by its habit, i.e. when organism is a little bit confused.

Situation of choice requires the simultaneity (synchronicity) of options. An organism can only have the freedom to make a decision if several possibilities are presented and

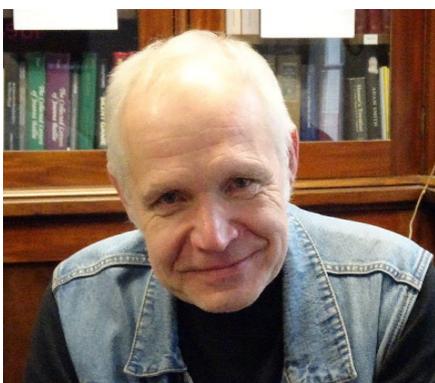
available at the same time. From the physicalist point of view, this may seem impossible – time is continuous and there is at least a microscopic difference between the events, thus everything is sequential. However, from organism’s point of view, the perceived time has a certain finite interval which is interpreted as present. From the physiological point of view, the specious present (Francisco Varela 1999) appears due to the finite relaxation times of coupled functional cycles. In this case, before a functional cycle can reach its action, there is another functional cycle that would lead to an alternative action, and if the actor is the same, then there is an incompatibility between the operations, hence there occurs a true situation of indeterminate choice. Moreover, the moment of choice is related to organism’s meaning making. This can be seen as the fundamental point that connects phenomenology, semiotics, and physiology.

Strictly speaking, only the process based on choice and learning, i.e., on semiosis or interpretation, provides the adaptiveness profoundly independent of natural selection. In a more detailed analysis, we can distinguish between six principal types of changes in living systems:

	mutational	plastic	interpretative, meaningful
neutral	random drift	self-organizational shift	unmotivated choice
adaptive	natural selection	homeostatic adjustment	motivated choice

Whether the indeterminacy based on incompatibility of behavioural habits, and its solution via choice, exists only in the animals with a nervous system, or can be identified also in other organisms, including at least some types of cells, remains to be studied. Where it exists, it provides a mechanism for ends-directed changes. This is a mechanism of internal teleology, as termed by Joseph Woodger (1929).

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Kalevi Kull is Professor of Biosemiotics in the University of Tartu, Estonia. His research focuses on general semiotics, semiotic approaches in biology, semiotic mechanisms of biodiversity, primary mechanisms of meaning-making, and the theory and history of semiotics and theoretical biology. He has studied biology and worked in theoretical and mathematical biology, as well as in experimental ecology, during the last 25 years in semiotics. His books include: *Jakob von Uexküll: A Paradigm for Biology and Semiotics* (2001), *Towards a Semiotic Biology: Life is the Action of Signs* (2011) *On Theoretical Biology: Life Science Between Mathematics and Semiotics* (2019).

AN EXTERNALIST TELEOLOGY

Dan McShea and Gunnar Babcock | Duke University, Durham NC, USA

Poor Aristotle. In trying to explain the persistent tendency of objects to fall, he had nowhere to turn but to their internal natures. It is in a rock's nature to go downward when it moves, he theorized. Today we have other resources. In particular, we have what we here call "field theory." Objects present near massive bodies are immersed in a gravitational field that persistently directs them toward the body. Poor Ernst Mayr. In trying to explain the seeming goal directedness of organismal development, he thought he had nowhere to turn but to internal "programs." He adopted the term teleonomy, in an attempt to distance the discussion from Aristotle, but he looked inward (like Aristotle) to the genes for the source of goal directedness. The problem is, as could have been clear even in Mayr's time, genes are not up to the job. The genome could be construed as a program, perhaps, and it is certainly central in development, but it does not have the capacity to direct development in a goal-directed fashion. Genes are switches, of a sort, turning on and off, or continuously regulating, the production of proteins. And they contain no blueprint, no map, sufficient to guide the development of macroscale organismal structures. Such guidance can only come from something larger than and external to the guided structures, what today are variously called gene activation patterns, biochemical gradients, or simply morphogenetic fields. Here we argue that guidance by external fields is a common feature of all teleological entities, from organismal tropisms to human artifacts. Sunflowers tracking the sun across the sky are guided by the light field emanating from the sun. A homing torpedo tracking a target ship is guided by the sound field emanating from the target ship. What's more, natural selection itself is a teleological process in which an evolving lineage is guided by an ecological "field." In all of these, the teleological guidance, the field, is external. Extending the reasoning even further, intentionality in organisms can be understood as a system in which a goal-directed entity, consciousness, is immersed in and directed by external "fields." Here the fields are affective processes – wants, preferences, cares, the passions, or simply the motivations – here conceived as larger than and enveloping the consciousness they direct. In this view, the affective processes themselves are in turn directed by the yet-larger social structures in which they develop, as well as the ecological fields that guided their evolution. In sum, it looks likely that the source of guidance for all goal-directed entities is external. And teleonomy, insofar as it turns its gaze inward, is looking in the wrong place.

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Dan McShea is Professor of Biology at Duke University. He received his Ph.D. from the University of Chicago, followed by postdoctoral positions at the University of Michigan and the Santa Fe Institute. His major papers have been on large-scale trends in the history of life, especially documenting and investigating the causes of the (putative) trend in the complexity of organisms. A significant part of this work has involved operationalizing certain concepts, such as complexity and hierarchy. More recently, he has been interested in goal directedness in biological systems, from simple organismal tropisms (bacteria swimming up a food gradient) to development (cell patterning and differentiation) to human artifacts (certain AI systems), and even to the goal directedness of natural selection itself and of human intentionality. He is author of *Biology's First Law* (2010), University of Chicago Press (with Robert Brandon) and the sequel, *The Missing Two Thirds of Evolutionary Theory* (2020), Cambridge University Press (again with Robert Brandon), as well as *Philosophy of Biology: A Contemporary Introduction* (2007), Routledge (with Alex Rosenberg).



Gunnar Babcock is a Postdoctoral Associate in the Department of Biology at Duke University. He received his PhD in philosophy from the University at Albany. His work focuses on lineages, individuality and goal-directedness in biology. It considers how biological individuals form lineages and the ways in which their interactions direct evolution and development. Some of this work appears in journals such as the *British Journal for the Philosophy of Science* and *Studies in History and Philosophy of Science*. Currently, he is working with Dan McShea in developing a theory that explains goal-directed phenomena by introducing an ontology of external fields. One aim of this work is to legitimize the use of teleology in the sciences generally.

WHEN THE END MODIFIES ITS MEANS: THE ORIGINS OF NOVELTY AND THE EVOLUTION OF INNOVATION

Armin P. Moczek | Indiana University, Bloomington, IL, USA

The origin of novel complex traits constitutes a central yet largely unresolved challenge in evolutionary biology. Of the four evolutionary processes conventionally recognized – natural selection, genetic drift, migration, and mutation, the first three can only sort among existing variants and their distribution within and among populations, but by themselves cannot bring about novel features. This privilege is instead restricted to mutation, yet all attempts to explain the evolution of novel complex traits solely via the coincident origin, spread, and fixation of one beneficial mutation at a time have failed. Exactly why, how, and when evolutionary innovations

occur and unfold the way they do has thus mostly eluded conventional molecular-, population-, and quantitative genetic approaches toward understanding the evolutionary process.

Intriguingly, many of the most promising breakthroughs in understanding the genesis of evolutionary novelty have occurred not in evolutionary biology itself, but through the comparative study of development and, more recently, the interface of developmental biology and ecology. Examining development across taxa, environmental contexts, and levels of biological organization has led to several key realizations. For example, organismal development has revealed itself to be a highly modular process, whereby phenotypic diversity is facilitated through the context-dependent re-use and re-assembly of an otherwise remarkably limited pool of genes, developmental pathways, cell types, and morphogenetic processes. Furthermore, organismic development has emerged as a highly constructive process, where a given aspect of phenotype formation builds upon a pre-existing phenotype created during previous stages of development. In this presentation I discuss how these and related insights are changing our understanding of what matters in the origin of novel, complex traits in ontogeny and evolution.

Specifically, my presentation has two major objectives: First, I discuss how the agential self-constructing and self-correcting nature of developmental systems biases the production of phenotypic variation in the face of novel or stressful environments toward functional, integrated, and possibly adaptive variants, thereby allowing the production of novel phenotypes to precede, rather than to follow changes in genotype. Second, I explore how this self-constructing and self-correcting agential nature itself has evolved over time, increasing the repertoire of developmental systems to pursue a wider range of objectives across an expanding range of conditions, thereby creating an increasingly extensive affordance landscape in development and developmental evolution. I support my arguments with examples from our own research on the ecological and evolutionary developmental biology of horned beetles in particular, and the developmental evolution of arthropods in general.

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Armin P. Moczek is a Professor of Biology at, Indiana University's Department of Biology, a fellow of the John Simon Guggenheim Foundation and the American Association for the Advancement of Science (AAAS), and holds the 2017 Fulbright Distinguished Chair in Science, Technology, and Innovation. He is an evolutionary developmental biologist broadly interested in understanding why and how developmental evolution has unfolded the way it has, why and how novel complex traits originated when they did, and the future of developmental evolution on a rapidly changing planet. In all of this, he pays particular attention to the mechanisms and

consequences of developmental plasticity, which growing evidence implicates as a key enabler of

evolutionary diversification. More recently, he has also become interested in symbiosis and niche construction as additional facilitators of evolutionary change. As a Masters student at the Julius Maximilians University in Würzburg, Germany, he was originally trained as a tropical biologist and worked on the ecological mechanisms maintaining arboreal arthropod diversity in the canopy of tropical rainforests in Sabah, Borneo, from 1992–94. In addition, he is broadly invested in the many dimensions of the teaching and learning of science. With colleagues from Indiana University’s School of Education he investigates the teaching and learning of complex systems in young children. In collaboration with WonderLab, a museum for Science, Technology and Health, and a team of graduate students and postdoctoral researchers he develops and disseminates teaching modules in support of K-12 Science Teaching Standards in public schools. And in close partnership with regional educators and university staff he founded and now co-directs a pipeline of three interdependent summer science programs for underrepresented minorities, aimed at changing the faces of STEM disciplines, from Junior High School through college and beyond.

CELLULAR AGENCY AND MESOSCALE PHYSICS IN THE EVOLUTION OF MULTICELLULAR DEVELOPMENT

Stuart A. Newman | New York Medical College, USA

Any entity that actively defines and regulates its own boundaries and sustains its integrity according to a set of internal motives and rules, can be regarded as possessing agency. In that sense, every living cell is an agent. Some multicellular organisms, particularly metazoans (animals), also exhibit agency. From where does this derive? I suggest that the evolution of multicellular agents involved the alignment, and eventual recruitment, of unicellular agency in the service of the evolving multicellular entity. This would entail the coordination and integration of the agency of individual cells as a prerequisite for the emergence of species-specific developmental programs from populations of unicellular ancestors. Unicellular agency could reemerge in the context of the neural crest pathways of the vertebrate embryo, for example, or in pathological states such as tumor metastasis. In this talk I will present a “physico-genetic” framework for the origination and development of the body plans and organs of animals. This is proposed to have involved the scaffolding of the single-cell behaviors of unicellular holozoan ancestors by mesoscale physical processes, e.g., adhesion, liquid-like and solidification effects, synchronization of chemical oscillators, that in many cases are “generic” or common to living and nonliving systems. Over time, with canalizing and stabilizing genetic evolution, primitive associations of agent-like cells would be converted into (in Immanuel Kant’s term) “natural purposes,” higher-level agents with inherent self-organizing modes of organization.

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Stuart A. Newman is a professor of cell biology and anatomy at New York Medical College, Valhalla, New York. Trained in chemistry (A.B., Columbia, Ph.D., University of Chicago) he then moved into biology, both experimental and theoretical, focusing on biophysical chemistry, embryonic



Developing Embryo (Cambridge, 2005) and (with Tina Stevens) of *Biotech Juggernaut: Hope, Hype, and Hidden Agendas of Entrepreneurial BioScience* (Routledge, 2019).

DOES THE CONCEPT OF TELEONOMY SOLVE THE PROBLEM OF ORGANISMIC PURPOSIVENESS?

Daniel J. Nicholson | George Mason University, Fairfax VA, USA

In discussions of teleology in biology, it is helpful to distinguish between extrinsic and intrinsic forms of purposiveness. A system is extrinsically purposive when its functions, operations, and behaviour serve the ends or reflect the actions or intentions of an external agent or process. A machine is a paradigmatic example of an extrinsically purposive system, as what a machine does serves the interests of its maker or user. On the other hand, a system is intrinsically purposive when its functions, operations, and behaviour serve its own ends, so that the system can be said to act on its own behalf. A person is a paradigmatic example of an intrinsically purposive system.

The philosophical worldviews of antiquity made room for both forms of purposiveness, which were typically attributed to inanimate as well as to animate entities. It is well known that the scientific revolution brought with it the repudiation of teleology, or purposiveness. What is less often remembered is that this repudiation was only of intrinsic purposes. While it was no longer acceptable to explain objects or processes by appealing to intrinsic purposes, it was still perfectly legitimate to infer from them the purposes or intentions of a Divine Creator. The mechanist worldview of early modern science was not only not incompatible with attributions of extrinsic purposes, but it necessarily presupposed them. The universe became a giant piece of clockwork designed by God, and it therefore reflected God's intentions.

With Darwin's theory of evolution by natural selection it became possible to explain the adaptation of biological systems to their environment without thereby presupposing the existence of a Divine Creator. Natural selection provided a scientifically respectable way of talking about extrinsic purposes in biology that made no reference to plans or intentions; that is, natural selection made it possible to explain adaptation without appealing to design. Eyes were understood to be made for seeing without having to presuppose that they were designed for seeing.

But what about intrinsic purposiveness? Historically, it seems clear that physics did very well after it gave up the appeal to intrinsic purposes. Biology, however, is another story. Virtually every generation of biologists since the seventeenth century has benefited from rediscovering Aristotle's appeal to intrinsic purposes whilst simultaneously feeling ashamed about doing so, as such appeals have generally been deemed incompatible with the mechanist worldview of modern science. Still, it is impossible to tell the story of nineteenth-century embryology and physiology, say, without recognizing the role played by teleological reasoning (of the intrinsic kind).

This unsatisfactory situation continued in the twentieth century. This is illustrated by Haldane's memorable quip that "teleology is like a mistress to a biologist: he cannot live without her but he's unwilling to be seen with her in public". Since then, several attempts have been made to eliminate, replace, or legitimize talk of intrinsic purposes. The most famous is Pittendrigh's proposal of the term 'teleonomy' in 1958, which he hoped would capture the purposiveness of organisms without thereby invoking the unpalatable connotations of the older concept of teleology.

However, the concept of teleonomy has not really helped matters. The reason is that 'teleonomy' has come to mean different things to different people. If anything, it has misled biologists into thinking that the problem of organismic purposiveness has been solved by terminological decree. As Hull has remarked referring back to Haldane's quip, "today the mistress has become a lawfully wedded wife. Biologists no longer feel obligated to apologize for their use of teleological language; they flaunt it. The only concession which they make to its disreputable past is to rename it 'teleonomy'".

The most common interpretation of the term 'teleonomy' is the one afforded to it by Mayr, who like Pittendrigh had been impressed by the cyberneticists' efforts to explain goal-directedness in terms of negative feedback. Mayr suggested that the teleonomy of an organism is unproblematic because it merely reflects the goal-directedness of its underlying 'genetic program'. The term 'genetic program', coined by Mayr alongside Jacob and Monod in 1961, was thus wedded to the concept of teleonomy from its inception. As Jacob put it, "the concept of programme has made an honest woman of teleology".

The problem with Mayr's proposal is that the genetic program idea is fraught with problems of its own. As a model of development, it is both empirically inconsistent

and conceptually unsound. Consequently, it is not likely to help us account for organismic purposiveness. A more promising approach, I will suggest, is to regard the intrinsic purposiveness of organisms as the empirical manifestation of the particular kind of organizational regime they exhibit. Our attention should therefore be directed towards elucidating the living organization. Only by understanding how living systems are internally organized will we arrive at an understanding of how their intrinsically purposive behaviours are causally produced.

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Daniel J. Nicholson is Assistant Professor of Philosophy at George Mason University. He holds a Ph.D. in Philosophy from the University of Exeter, an M.A. in History and Philosophy of Science from the University of Leeds, and an M.Biol. in Molecular and Cellular Biology from the University of Bath. Previously, he held appointments at the Konrad Lorenz Institute for Evolution and Cognition Research near Vienna, the Centre for the Study of Life Sciences in Exeter, and the Cohn Institute for History and Philosophy of Science and Ideas in Tel Aviv. Currently he is a Mercator Fellow at Ruhr-Universität Bochum and a Sydney Brenner Research Fellow at the Cold Spring Harbor Laboratory Center for Humanities and History of Modern Biology. In

the past he has been a visiting fellow at the University of Sydney and at the Universidad Nacional Autónoma de México.

PHYSIOLOGY AND TELOS: IS TELEOLOGY A SIN?

Raymond Noble | University College London, UK

Denis Noble | Oxford University, UK

Life is purposefully creative in a continuous process of maintaining integrity; it adapts to counteract change. This is an ongoing, iterative process. Its actions are essentially directed to this purpose. Life exists to exist. In doing so it creates purposive action; that is action directed to achieving goals created by life itself. This purpose is understood only in such contextual logic. Continuing to exist encounters problems that are then overcome through such purposive action; the purpose then being to overcome the obstacle in the way of achieving a goal. Problem-solving is purposeful. Purpose comes from creative functionality. This creative functionality has not only physiological and behavioural, but also an evolutionary dimension.

Physiology is the study of purposeful living function. Function necessarily implies purpose. This was accepted all the way from William Harvey who identified the

purpose of the heart to pump blood and so feed the organs and tissues of the body, through to Claude Bernard who identified the functions of the liver and other organs, to Bayliss and Starling who discovered hormones and their purposes, and to many other examples.

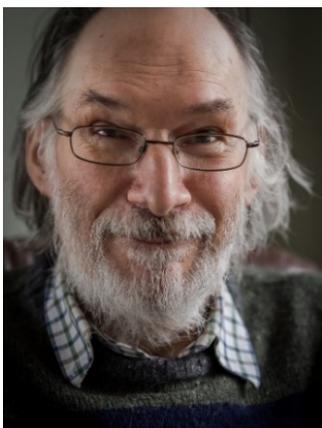
But late 20th century physiology was obliged to hide these ideas in shame. Teleology became the “lady who no physiologist could do without, but who could not be acknowledged in public.” This emasculation of the discipline accelerated once the Central Dogma of molecular biology was formulated, and once physiology had become side-lined as concerned only with the disposable vehicle of evolution.

Our presentation will show why this development has to be reversed. Even on the practical criterion of relevance to healthcare, gene-centrism has been a disaster. But there are also cultural downsides. The understanding of living systems is one of the great purposes of academic enquiry. If teleology is a sin, then we have got the wrong ethics.

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Denis Noble was the first to develop computer models of the heart and its electrical rhythm, published in *Nature* in 1960. As Secretary-General of the *International Union of Physiological Sciences (IUPS)* he played a major role in launching the *Human Physiome Project*. He was President of IUPS (2009-2017). He is one of the founders of the field of *Systems Biology* and is the author of the first popular science book on the subject, *The MUSIC of LIFE* (Oxford University Press 2006), which has now been translated into 12 other languages. He has authored many other books, including his most recent one, *Dance to the Tune of Life* (Cambridge University Press, 2016). He now collaborates with Raymond Noble on the nature of causality in biological systems and the philosophy of science. They are writing a new book together.



Raymond Noble studied zoology at Manchester University in the 1970s and for a PhD in neuroscience at Edinburgh University where he worked on somatosensory function in mammals. He joined the faculty at University College London with a Rockefeller Senior Research Fellowship with a joint appointment in physiology and in obstetrics and gynaecology where he worked on foetal and neonatal physiology and medical ethics. He was Graduate Tutor of the UCL Institute for Women's Health and Deputy Dean of life sciences, and established a centre for reproductive ethics working on barriers to access to health care for women. He holds an honorary appointment at UCL where he continues his interest in the nature of causality in biological systems and the philosophy of science.

TELEONOMY, AGENCY, AND UNITY OF PURPOSE

Samir Okasha | University of Bristol, UK

The use of teleological, or apparently teleological, concepts and descriptors is rife in biology, as has often been noted. Mayr's celebrated distinction between teleology and teleonomy can be seen as an attempt to delimit an objective and scientifically interesting form of goal-directedness in biology, based around the notion of a genetic program, and to distinguish it from more questionable forms of teleology that are metaphorical and/or are anthropomorphic in origin. Mayr's concept of teleonomy is still useful today, but it includes two different sorts of phenomena: *activities* of a whole organism (e.g. foraging, migrating), and internal processes (e.g. gastrulation, gametogenesis). This is a crucial distinction. In my recent book, *Agents and Goals in Evolution* (OUP 2018), I argue that when we describe an organism's activities as goal-directed, we presuppose that the organism exhibits a "unity of purpose", which means (roughly) that all of its traits contribute towards a single overall goal; this in turn requires the (near) absence of internal (or intra-genomic) conflict. In this paper, I explore how the unity-of-purpose condition relates to Mayr's original discussion of teleonomy.

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Samir Okasha is Professor of Philosophy of Science at the University of Bristol, U.K. He received his doctorate in 1998 from the University of Oxford. His research interests focus on philosophical, methodological, and conceptual issues in the natural sciences, in particular evolutionary biology. He also researches epistemological issues concerning the nature of scientific inference, inductive reasoning, and causality. He is the author of two monographs, two introductory books, and over seventy articles in leading philosophical and scientific journals. His 2006 book *Evolution and the Levels of Selection* was awarded the Lakatos Prize 2009 for an outstanding contribution to the philosophy of science. He currently serves as President of the European Philosophy of Science Association (EPSA). He is a Fellow of the British Academy.

TELEONOMY AND GENOME CHANGE

James A. Shapiro | University of Chicago, USA

Genome change does not occur accidentally. Replication proofreading, cell division checkpoints, and error-free repair functions reduce accidental changes to very low levels (e.g., ≤ 1 per 10^9 – 10^{10} nucleotide incorporations). Elevated levels of change occur

in response to stress or damage and involve dedicated biochemical systems that alter DNA sequences, restructure DNA molecules or execute error-prone mutagenic repair functions. Since mutational natural genetic engineering (NGE) systems are present in all cells, including *Mycoplasma* species with the smallest naturally evolved genomes, it appears that the capacity for genome self-modification is a fundamental property of living organisms that enables them to evolve when challenged by ecological disruption.

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James A. Shapiro is Professor of Microbiology in The Department Of Biochemistry and Molecular Biology at the University Of Chicago. He received his B.A. in English Literature from Harvard in 1964 and his Ph.D. in Genetics from Cambridge University in 1968 under Prof. W. Hayes, FRS. After postdoctoral fellowships at Institut Pasteur with Prof. Francois Jacob (1967-1968) and Harvard Medical School with Prof. Jonathan Beckwith (1968-1970), he served as Invited Professor in the School of Biological Sciences at the University of Havana, Cuba (1970-1972). At the University of Chicago since 1973, he was Darwin Prize Visiting Professor at the University of

Edinburgh (1993). In 2001, he received an O.B.E. from Queen Elizabeth for services to the Marshall Scholarship Program. He is a founding member of the web site, www.TheThirdWayofEvolution.com, which is intended to make the public aware of scientific alternatives to both Intelligent Design and Neo-Darwinism. He has published pioneering books on mobile genetic elements, natural genetic engineering, bacterial multicellularity, and read-write genome evolution, including: Bukhari, A.I., J.A. Shapiro, and S.L. Adhya (eds.) 1977. *DNA Insertion Elements, Plasmids and Episomes*, Cold Spring Harbor Laboratory. Shapiro, J.A. (ed.) 1983. *Mobile Genetic Elements*, Academic Press. Shapiro, J.A. and M. Dworkin (eds.). 1997. *Bacteria as Multicellular Organisms*, Oxford University Press. Shapiro, J.A. 2011. [*Evolution: A View from the 21st Century*](#). FT Press Science (ISBN-10: 0-13-278093-3; ISBN-13: 978- 0-13-278093-

TOWARD A THOUGHT-FULL TELEOLOGY – BEYOND THE HOLLOW ORGANISM

Stephen Talbott | The Nature Institute, Ghent NY, USA

The language of teleology, or purposiveness, is ubiquitous and seemingly unavoidable in biological description. And yet biologists have long seemed conflicted about their use of this language — as if they were somehow being tricked into continually misspeaking, or as if things were not quite what they appeared to be.

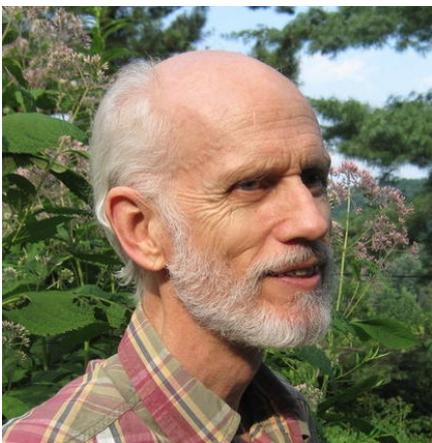
At least part of the problem is that teleological language all too easily evokes thought, intelligence, and consciousness, which in turn might suggest psyche, soul, entelechy, or other untouchable ideas. So various overlapping stratagems are employed to eliminate the dangers of teleological language. One is to “naturalize” the language by claiming that “purposiveness” (such as it may be) is, in one way or another, a non-problematic result of natural selection. Another is to apply machine models of purposive action to organisms. (Think, for example, of cruise missiles and feedback mechanisms.) The idea of teleonomy comes in here.

I briefly argue against both these approaches. But I give most attention to a third stratagem for taking the sting out of teleological language. It involves a refusal to grant thought, intelligence, and consciousness entry into biological discourse, apart from certain “special cases” (such as we humans) considered to be of no deep import for the greater evolutionary drama. The underlying problem here is that biologists in general seem poorly disposed toward *actual* thought, intelligence, and consciousness in favor of the various interior-less (“hollow”) mechanisms onto which these capacities can be projected.

Yet the fact remains that our interior life constitutes the one evolutionary achievement we know from the inside. Our wide-awake, self-aware experience provides the first inner space within the kingdoms of life on earth where evolution can rise to consciousness, reveal its true nature, and even submit to our direction. We need to come to terms with the connections between our own highest functioning, the intelligence of the cells in our bodies, and the entire creative drama of life on this planet. The central aim of my presentation will be to suggest the nature of these connections.

Background writings underpinning some parts of this presentation are available at <http://BiologyWorthyofLife.org/bk>.

Registered attendees can address questions about this talk to: stevet@natureinstitute.org



Stephen L. Talbott has been a senior researcher at The Nature Institute in Ghent, New York, since its founding in 1998. He is currently working on a book titled *Evolution as It Was Meant to Be — And the Living Narratives That Tell Its Story*. All chapters are being made available online as they are written: <http://BiologyWorthyofLife.org/bk> (or <https://bwo.life/bk>).

TELEOPHOBIA

Denis Walsh | University of Toronto, Canada

Teleology—the explanation of phenomena by appeal to the goals that they subserve—is widely thought to have been expunged from biology. The reasons generally offered for the putative banishment of teleology are numerous and varied—historical, conceptual, theoretical, metaphysical—and they are all wrong. There is no defensible reason for the teleophobia that holds contemporary biology in its grip. Furthermore, teleophobia has had a demonstratively deleterious effect on the development of evolutionary theory. It has aided and abetted the marginalisation of organisms from evolutionary thinking. Organisms, I argue, are natural purposes. The pursuit of organismal purposes makes a difference to the dynamics of evolution that can only be fully explained teleologically. Teleology must thus form an indispensable part of the evolutionary biologist’s methodological toolkit.

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Denis Walsh is a Professor in the Department of Philosophy, the Institute for the History and Philosophy of Science and Technology, and Department of Ecology and Evolutionary Biology at the University of Toronto. He completed a Ph.D. in Biology at McGill University and a Ph.D. in Philosophy at King’s College London. He has taught at LSE, University of Edinburgh, Dartmouth College, and MIT. He is the author of *Organisms, Agency, and Evolution* (Cambridge University Press, 2015).