*41st ALTENBERG WORKSHOP IN THEORETICAL BIOLOGY*

# *Sociocultural EvoDevo & Cognition: The Role of Cultural Neurobiological Inheritance Systems (CNIS)*

*organized by*

*Isabella Sarto-Jackson & Daniel O. Larson*

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*KLI Klosterneuburg, Austria*

## Welcome

to the 41st Altenberg Workshop in Theoretical Biology. The Altenberg Workshops are interdisciplinary meetings organized by the KLI in Klosterneuburg, Austria. The workshop themes are selected for their potential impact on the advancement of biological theory. Leading experts in their fields are asked to invite a group of internationally recognized scientists for three days of open discussion in a relaxed atmosphere. By this procedure the KLI intends to generate new conceptual advances and research initiatives in the biosciences. We are delighted that you are able to participate in this workshop, and we wish you a productive and enjoyable stay.

Philipp Mitteroecker
President

## The topic

The aim of the proposed workshop is to bring together a group of internationally recognized scholars to discuss a theory of human cognition based on Sociocultural EvoDevo. This theoretical framework calls attention to how cultural context, neurobiology, and human ontogeny are integrative. Representatives from multiple fields, including neurobiology, anthropology, evolutionary developmental biology, social psychology, and human development, will be invited to participate in focused discussions on topics that challenge traditional, gene-centric, and deterministic views on cognition. We will specifically probe the integrative dynamics of cultural context, neuroplasticity, learning, memory, neurotransmitters, and emotions. This evaluation will be key to operationalizing a theory of proximate and ultimate causes of cross-cultural human cognition and behavioral expressions. The group will evaluate how to best bridge disciplines in order to generate novel concepts, suggest hypothesis testing programs, and structure interdisciplinary research designs as well as advanced methods and technologies, including AI and Quantum Computing. We believe that this is a very timely endeavor since contemporary intra-disciplinary specialization frequently neglects these kinds of integrative issues. Indeed, intergenerational and transgenerational inheritance of behavioral propensities should be measured in cultural, developmental, and neurobiological dimensions. We anticipate that the research agenda explored and subsequently reified in the proposed workshop will be directive and pioneering.

**Neuroplasticity and Human Behavior**

Flexibility and plasticity in behavior and cognition are considered evolutionary adaptations to environmental variations. In addition, flexibility and plasticity are means by which adjustments to changing social and environmental circumstances can be fast and frugal. In contrast, genetic change is notoriously slow and inadequate in responding to the punctuated tempo, duration, and frequency of rapid events. The human brain and its resulting cognitive capacities hold a special position in this discussion about organismal flexibility as the brain's extraordinary malleability relies on neuroplastic processes. Neuroplasticity is the ability of synapses and neuronal networks to become strengthened or weakened over time, in response to increases or decreases in their activity triggered by external stimuli. Connectivity of synapses and neuronal networks become established during development within constraints set by genetics. The selective stabilization of functional connections prunes redundant or inactive networks and contribute to brain maturation. In other words, these processes describe the brain as a selectional system operating within an individual's lifetime (Edelman, 2006; Fernando,

Szathmary, and Husbands, 2012), as opposed to the traditional view of the brain as an instructional system (i.e., blueprint view).

These adaptive changes represent the neurochemical and systemic foundations of learning and memory (i.e., Hebbian theory). Neuroplastic processes are self-organizing and emergent from neurophysiological, environmental, cultural, and social contexts. Thus, neuroplasticity is tightly intertwined with cultural learning and socio-culturally embedded scaffolding (Caporael et al., 2014; Sarto-Jackson et al., 2017), both strongly affecting cognitive development. Hence, neuroplastic processes connect the organism's biology with its environment strongly arguing against a nature–nurture divide.

Despite the importance of the aforementioned processes (neuroplasticity, neuronal competition, pruning, and selective stabilization) for ontogeny, there is no widely accepted mechanism by which functional variations in neurobiological phenotypes or any kind of synaptic connectivity patterns can be inherited. This certainly holds true for transgenerational information transfer when limited to genetic inheritance.

**Key Questions Addressed at the Workshop**

In this Workshop we want to explore the potential development of Sociocultural EvoDevo Theory, which challenges the view that neurobiological variations are not subject to inheritance if they lack transmission of a genetic substrate. We anticipate that the Workshop will contribute to the development of a theoretical framework that understands human cognition as a product of evolution and development that emerges in a natural and social context and expounds non-genetic processes of inter- and transgenerational transmission of cognitive traits.

The framework of Sociocultural EvoDevo is derived from decades of scholarly works that question many of the notions of the Modern Synthesis including the conceptual pre-eminence of natural selection, exclusive genetic inheritance, gradualism, and macro-evolution (Jablonka and Lamb, 1995, 2020; Laland et al., 2015; Müller, 2007; Müller and Newman, 2005; Pigliucci and Müller, 2010; Sansom and Brandon, 2007). Phenotypic behavioral plasticity is at the core of the Extended Evolutionary Synthesis and EvoDevo perspectives, and it is also the foundation for Sociocultural EvoDevo.

Our perspective is guided by the view that inclusive inheritance "extends beyond genes to encompass (transgenerational) epigenetic inheritance, physiological inheritance, ecological inheritance, social (behavioral) transmission, cultural inheritance, and niche construction broadly conceived. Acquired characters can play evolutionary roles by biasing phenotypic

variants subject to selection, modifying environments, and contributing to heritability" (Laland et al., 2015:2; also see Plotkin, 1988:8). Although Sociocultural EvoDevo is interested in all of these interactive systems, it is especially focused on social (behavioral) transmission and cultural inheritance.

Our view of culture is multidimensional, and we acknowledge that the human "behavioral substrate unfolds at several explanatory levels - from the molecular, neurobiological, to the information processing of neural networks dynamics, to mental states, and eventually social cognition. It stands, thus, to reason that behavior itself can only be comprehensively understood from the highest hierarchical landing, viz. within the social and cultural context that shape thought and action" (Sarto-Jackson et al., 2017:730).

Stated succinctly the principles of Sociocultural EvoDevo are:

- Human cognition is grounded in social context involving attachment, intrinsic motivation as well as rewards or punishment as experienced by the individual's contextual interactions with conspecifics.
- Specific cultural histories, in their multiple dimensions, produce conceptual or cognitive inheritance of norms of appropriate and inappropriate behavior.
- During hominid evolution, natural and social pressures selected for and co-evolved various genetic traits, neural processes, behavioral propensities, and sociocognitive competencies.
- Ontogeny/development is the context in which the organism learns to communicate and interact with parents and peers, and our evolved cognitive capacities drive behavioral conformity via neurobiological structures (see below) that are sculpted by positive and negative experiences.
- Both cultural and neurobiological plasticity are key processes responsible for creating a most intriguing individual as well as a group collective adaptive process that affects expression of human behavior on micro- and macro-spatial and temporal scales.
- Agency is at the core of our theoretical perspective and how and why an individual makes decisions is our subject matter.

The greatest advantage of the Workshop is that the invited scholars will have the opportunity to restructure, build, and improve the existing draft framework for Sociocultural EvoDevo.

**Filling the Research Gap of Cognitive Inheritance**

One of the major driving issues confronting our Workshop group pertains to the concept of inheritance. Specifically, how can we link culture, individual experience, neurobiological processes, and inheritance systems?

To fill the research gap of cognitive inheritance, we have proposed a new conceptual perspective termed Cultural Neurobiological Inheritance Systems (CNIS).

Generally, CNIS includes neurobiological structures and systems that are formed by experiences. CNIS is inherited vertically and horizontally, and the strength of transference and fidelity are dependent on the intensity of cultural learning and concomitant effects on neuroplasticity, neurotransmitters, and the development of emotional systems.

We strongly acknowledge that coupling genetic and epigenetic inheritance systems provides a new view on co-inheritability of biological and environmental factors affecting transmission of inheritability of progenitor cells (Hallgrimsson and Hall, 2011; Kundakovic and Jaric, 2017). However, CNIS is different from genetic and epigenetic inheritance.

CNIS also affects biology, but we stress the inheritance of functional neural networks and neurochemical levels of neurotransmitters and -modulators, emphasizing the functional, not the anatomical level. Both are affected by experiences, mainly from parents, peers, and social groups and include change to neurobiological structures/networks related to social attitudes, language systems, taste preferences, and many more cultural dimensions by use of sociocultural niches and processes of scaffolding.

The issue that we find most interesting with regard to human behavior is related to how these functional structures are influenced by experience and precisely how neural networks become wired by experience as a result of cultural and individual contexts. In addition, we would like to know how neurochemistry and emotions are precisely related to neuroplasticity and previous experiences.

Cultural Neurobiological Inheritance Systems, a foundational concept of Sociocultural EvoDevo, is designed to explicitly address the research gap of cognitive inheritance. We argue that memory and related neurobiological processes shaped by experience are anchored in discrete, physiological substrates of the human brain. In short, CNIS represents the physical trace of memory in the neural architecture, providing an interface between human experience and the functional biological underpinnings of cognition.

**Incorporating Bayesian Theory and Predictive Modeling**

We argue elsewhere that integrating Bayesian Theory, Predictive Processing, and Active Inference provides a robust foundation for Sociocultural EvoDevo. These conceptual frameworks elucidate how the brain minimizes prediction errors, continuously refining its internal models in response to sensory information and related learning. Such principles underscore the brain's inherent drive to anticipate and adapt to its environment, thereby illuminating the predictive mechanisms governing cognitive processes and behavioral responses. All of which are shaped by previous individual experience and cultural context.

We argue that cultural experiences and norms sculpt our neural circuitry through synaptic plasticity and social learning mechanisms. In Bayesian terms, these cognitive structures represent *priors*, the human brain's expectations, or predictions about the state or context a phenotype encounters at any given moment. These *priors* are explicit, context-specific hypotheses about sensory states that are continuously revised based on incoming sensory input.

We propose that cultural norms, refined across both micro and macro temporal scales, can effectively function as *priors*, facilitating decision-making processes for individual agents as well as influencing the collective behaviors of social groups. These norms, while functionally selected (optimization), can also exhibit non-functional characteristics (style). This body of research resonates profoundly with our framework of Cultural Neurobiological Inheritance Systems (CNIS), underlining the complex interplay between culture and neurobiology. From a neurobiological standpoint, the history of experiential learning, CNIS, and extended behavioral interactions construct neurobiological *priors*, manifesting as belief systems. In essence, CNIS represents a pivotal element in the nexus between cultural experience and neurobiological development, underpinning the formation of Bayesian predictive modeling and Predictive Processing in the human brain.

**Why the Workshop Topic is Timely and Necessary**

Neuroscientists and social scientists are making significant discoveries in studying how human neurobiology and behavior are interactive, self-organizing, and emergent. There is incontrovertible neurobiological evidence that neural networks are not genetically predetermined, but dynamically generated deriving from experience, neuroplasticity, development, and context – individual and cultural.

It has been well demonstrated that neuroepigenetics can have a profound influence on human memory, emotions, neuroplasticity, and behavior. Sociocultural EvoDevo is particularly interested in the effects of non-genetic inheritance, like CNIS, and concomitant epigenetic shifts.

One of the objectives of the Workshop will be to discuss and incorporate this perspective into the framework of Sociocultural EvoDevo and CNIS. What is abundantly clear is that if we do not understand cause and effect relationships related to sociocultural context, development, and neurobiology, we cannot intervene effectively (Sarto-Jackson, 2017, 2022). According to Wimsatt and Griesemer (2007:227), models of cross-cultural behavior typically "black box human ontogeny and developmental acquisition of cultural traits and describe inheritance as only mapping relation between 'parents' and cultural 'offspring'." Sociocultural EvoDevo aims to offer scholars a way out of this dilemma.

**CNIS and Multilevel Selection**

Sociocultural EvoDevo specifically challenges contemporary accounts that map organismal behavior in a linear fashion onto genetic makeup as well as molecular or physicochemical brain processes. This new perspective poses a unique and intriguing question – should we extend the concept of non-genetic or inclusive inheritance to include neurobiological structures and systems that are formed by experiences, like emergent and self-organizing CNIS?

Such neurobiological variations were no doubt subject to natural and cultural selection during human evolution. Indeed, variations in CNIS that maintained social and neurobiological homeostasis between close kin may have been a source of adaptive advantage in human evolution. Conceptually, this argument aligns with previous group selection arguments, possibly making CNIS a theoretical bridge that connects multilevel evolutionary processes in human prehistory.

**Unified Science of Human Behavior**

Here, we have outlined the conceptual framework of Sociocultural EvoDevo and CNIS. We challenged the notion that neurobiological variations are not subject to inheritance if they lack transmission of a genetic substrate.

This evaluation may be key to operationalizing a Unified Theory of proximate and ultimate causes of human behavioral expressions.

During the 1920s, meetings in Vienna attended by philosophers, scientists and psychologists were held in a bold effort to try and bridge fields for the specific purpose of building a common Unified Theory. We think that with extraordinary advances in our collective fields, in both theory building and empirical research, it is time to rekindle this one-hundred-year-old intellectual pursuit.

## Conclusion

In closing, this is by no means a finished theoretical argument for explanations of the complexities of human behavior. That will require more time and scholarly contributions from others. In fact, this was the objective of this Workshop as we initially envisioned it. We welcome all criticisms, alternative perspectives, corrections, and constructive changes that will improve this early-stage theoretical framework.

Finally, we will leave you with two quotes key to our thinking about Sociocultural EvoDevo and CNIS. It is Gerald Edelman's first principles in human evolution and neurobiology –

"that is, the human brain is embodied, and the body and brain are embedded in the world. They act in the world and are acted upon by it." (2006:25)

The second is by Albert Einstein and Leopold Infeld

"…imagination was needed to realize fully that not the behavior of bodies, but behavior of something between them, that is, the field may be essential for ordering and understanding events." (1938:295)

## References


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**Format**

There will be 17 presentations, with 50 minutes allotted for each – roughly 30-35 minutes for each talk, followed by 15-20 minutes for questions on that talk and discussion. On Wednesday we kick off with an introductory statement by the organizers, addressing the aims and framework of the workshop; on Friday we end the scientific program with a general discussion and publication plans.

For our workshop speakers who want to participate online, we have set up a Zoom link:

https://us02web.zoom.us/j/83675830759

Meeting ID: 836 7583 0759

**Manuscript preparation and publication**

The Altenberg Workshops in Theoretical Biology are sponsored by the KLI. In turn, the Institute asks participants to contribute a paper to a volume edited by the organizers. Altenberg Workshop results are usually published in the *Vienna Series in Theoretical Biology* (MIT Press). The volume will further develop the novel ideas and concepts generated as a result of the workshop. The contributors are not necessarily limited to the original participants; they may be complemented by experts on those topics that emerge as important and may include co-authors invited at the discretion of the participants. Because of the explicit interdisciplinary nature of the effort, the outcome should be attractive to a wide range of experts in the natural and social sciences as well as in the humanities.

We hope that participants will draft their manuscripts as a result of our discussions at the workshop and the ensuing review process (probably "round-robin," during which commentaries will be elicited for each paper from two selected members of the workshop). We are aiming for a January 31, 2025, date for receipt of manuscripts. The length of the contributions should be approximately 8,000 words. The use of figures and photographs is highly encouraged. All contributions will be edited for style and content, and the figures, tables, and the like will be drafted in a common format. The editors will send specific instructions after the workshop.

Thank you, and we look forward to the Workshop.

Isabella Sarto-Jackson and Daniel Larson

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# Sociocultural EvoDevo & Cognition: The Role of Cultural Neurobiological Inheritance Systems (CNIS)

| Tuesday<br>18 June | Evening | | |
|---|---|---|---|
| 6.00 pm | Dinner @KLI | Welcome reception and dinner | |

| Wednesday<br>19 June | Morning | A Novel Evolutionary Theory for Cognition? | Chair: Markus Kunze |
|---|---|---|---|
| 9.30 am – 10.15 am | Daniel Larson & Isabella Sarto-Jackson | Sociocultural EvoDevo Theory and CNIS: A Rough Draft | |
| 10.15 am – 11.05 am | Kevin Lala | Evolution Evolving: Human Cognition in Light of the New Biology | |
| 11.05 am – 11.30 am | Coffee | | |
| 11.30 am – 12.20 pm | Christine Caldwell | Interdependencies between Human Cognition and Culture: How Do We Flesh out the Details of Coevolutionary Accounts? | |
| 12.20 pm – 12.40 pm | Markus Kunze | Setting the Scene – Discussion | |
| 12:40 pm – 2.00 pm | Lunch @KLI | | |

| Wednesday<br>19 June | Afternoon | Sociocultural Evolution &<br>Neurobiological Inheritance | Chair:<br>Sophie<br>Veigl |
|---|---|---|---|
| 2.00 pm – 2.50 pm | Michael Tomasello *(online)* | Cultural Coordination and Uniquely Human Cognition | |
| 2.50 pm – 3.40 pm | Ehud Lamm | Collective Knowledge or Collective Inheritance? | |
| 3.40 pm – 4:10 pm | Coffee | | |
| 4.10 pm – 5.00 pm | Oded Rechavi | Thinking Transgenerational Inheritance | |
| 5.00 pm – 5.50 pm | Isabelle Mansuy *(online)* | How Traumatic Experiences in Early Life Can Affect Descendants via the Germline | |
| 5.50 pm – 6.20 pm | Sophie Veigl | Discussion | |
| 6.30 pm | | Departure for dinner at a local Heurigen | |

| Thursday<br>20 June | Morning | Developmental Plasticity &<br>Substrates of Cognition | Chair:<br>I. Sarto-Jackson |
|---|---|---|---|
| 9.30 am – 10.20 am | Barbara Fischer | Modelling the Evolution of Sensitive Windows in Animal Development | |
| 10.20 am – 11.10 am | Claudia Buss<br>*(online)* | Intergenerational Transmission of Maternal Childhood Maltreatment and the Role of Fetal Programming | |
| 11.10 am – 11.40 am | Coffee | | |
| 11.40 am – 12.30 pm | Annelies Hoorn | Temporal Dynamics of Neuronal Excitability in the Lateral Amygdala Mediates Allocation to an Engram Supporting Conditioned Fear Memory | |
| 12.30 pm – 1.00 pm | Sarto-Jackson | Discussion | |
| 1.00 pm – 2.10 pm | Lunch | at the KLI | |

| Thursday<br>20 June | Afternoon | Development, Behavior & Neurodynamics | Chair:<br>Markus Kunze |
|---|---|---|---|
| 2.10 pm – 3.00 pm | Regina Sullivan *(online)* | Mechanisms of Neurobehavioral Intergenerational Transmission of Infant Attachment and Trauma | |
| 3.00 pm – 3.50 pm | Francesca Cirulli | Embedding Early Experiences into Brain Function: Understanding the Neurobiological Mechanisms to Improve Resilience in the Face of Adversity and Build the Foundation of a Healthy Life | |
| 3.50 pm – 4:20 pm | Coffee | | |
| 4.20 pm – 5.10 pm | Igor Branchi | Uncovering the Determinants of Brain Functioning, Behavior and Their Interplay in the Light of Context | |
| 5.10 pm – 6.00 pm | Eörs Szathmáry | Darwinian Neurodynamics: True Evolution on the Millisecond Scale? | |
| 6.00 pm – 6.30 pm | Markus Kunze | Discussion | |
| 6.30 pm | | Free evening | |

| Friday<br>21 June | Morning | Towards a Unified Framework of Cognition | Chair: Alejandro Villanueva |
|---|---|---|---|
| 9.30 am – 10.20 am | Antonella Tramacere | Scaling Up Embodied Perspectives in Cognitive Evolution | |
| 10.20 am – 11.10 am | Adam Linson | Cultural Pressure on the Evolution of Cognitive Flexibility: Polyvalent Perception, Context Modulation, and Planning as Inference | |
| 11.10 am – 11.40 am | Coffee | | |
| 11.40 am – 12.20 pm | Isabella Sarto-Jackson & Daniel Larson | Wrap-up: Advancing the Concept of Cultural Neurobiological Inheritance Systems (CNIS) | |
| 12.20 pm – 12.50 pm | Alejandro Villanueva | General Discussion | |
| 12.50 pm – 1.00 pm | | Publication Plans | |
| 1.00 pm – 2.10 pm | Lunch | at the KLI | |
| 2.10 pm | | Boat trip on the Danube & dinner<br>*(please bring your passport!)* | |

# Abstracts

**Daniel O. LARSON**

California State University Long Beach

&

**Isabella SARTO-JACKSON**

Konrad Lorenz Institute for Evolution and Cognition Research

**Sociocultural EvoDevo Theory and CNIS: A Rough Draft**

This talk presents a new theoretical perspective, which we term Sociocultural EvoDevo. Traditionally, social scientists have viewed the human brain as a "black box" of behavior. At the same time, advancements in the neurosciences tempt us to perceive behavior as a linear extension of brain processes. Sociocultural EvoDevo specifically challenges contemporary accounts that map organismal behavior in a linear fashion onto genetic makeup as well as molecular or physicochemical brain processes. We advocate for an alternative research structure that explores the integrative dynamics of cultural context, neuroplasticity, learning, memory, neurotransmitters, and emotions as key components to explicating the multidimensionality of cross-cultural human behavior. But how can we link culture, individual experience, neurobiological processes, and inheritance systems? To address this research gap, we incorporated Cultural Neurobiological Inheritance Systems or CNIS as a foundational concept of Sociocultural EvoDevo, particularly for cognitive inheritance.

We argue that memory and related neurobiological processes shaped by experience are anchored in discrete, physiological substrates of the human brain. In short, CNIS represents the functional physical trace of memory in the neural architecture, providing an interface between human experience and the functional biological underpinnings of cognition. We suggest that CNIS is inherited both vertically and horizontally, and the strength of transference and fidelity is dependent on the intensity of cultural learning and its simultaneous effects on neuroplasticity, neurotransmitters, and the development of emotional systems. Sociocultural EvoDevo specifically explains how human cognition is shaped by both evolution and development and how it is self-organizing and emergent in a social context. We argue that intergenerational and

transgenerational inheritance of behavioral propensities should be measured in cultural, developmental, epigenetic, and neurobiological dimensions. Our perspective significantly differs from definitions of inheritance provided by mainstream biology and evolution theorists; however, it is consistent with EvoDevo and the Extended Evolutionary Synthesis.

**Kevin N. LALA**

University of St Andrews

**Evolution Evolving: Human Cognition in Light of the New Biology**

Evolutionary biology is currently coming to terms with a rush of striking findings that challenge the orthodox narrative. Among the most important recent advances in evolutionary understanding is the realization that the evolutionary process itself evolves. Organisms differ greatly in how good they are at evolving. That is because natural selection is not something that just happens to organisms: their activities and behaviors contribute to whether and how it happens. The form that natural selection takes depends critically on the mechanistic details of how each organism operates – its development, physiology and behavior. There are three requirements for natural selection: (1) there must be trait variation among individuals in a population (*phenotypic variation*), (2) individuals with some variants must leave more descendants than others (*differences in fitness*), and (3) offspring must resemble their parents more than they resemble unrelated individuals (*inheritance*). These requirements hold for all organisms, but how they are met differs from case to case. For instance, forms of inheritance differ greatly across organisms. A profusion of resources other than genes are now known to be passed down the generations, including hormones, symbionts, epigenetic changes, antibodies, ecological resources, and learned knowledge, and this variation, too, can be selected, and generate adaptation. Organisms need to be able to cope with environments that fluctuate on all temporal and spatial scales, and extra-genetic inheritance plays a vital role in short-term adaptation. Culture can be understood in this way. It is not something that separates humans from nature, it is a critical part of our nature: a biological property whose function is to allow humans to adapt to rapid change. Different capabilities to modify environments (a.k.a. 'niche construction') and to develop flexibly (a.k.a. 'phenotypic plasticity') further underpin variation in evolvability. Humans are champion niche constructors. Acceptance that the evolutionary process evolves allows rich explanations for human evolution to be based on scientifically validated and widely observed natural processes. Humans do not evolve like mice, fruit flies, or yeast. We interpret natural selection differently because we develop differently, interact with the world differently, and inherit selectable variation differently. Those differences matter because the way humans are set up to evolve determines how we behave.

**Christine A. CALDWELL**

University of Stirling

**Interdependencies between Human Cognition and Culture: How Do We Flesh out the Details of Coevolutionary Accounts?**

The puzzle of human distinctiveness has long fascinated theorists. Apparently unique features of human cognition have sometimes been attributed to humans' unrivalled capacity for cultural transmission. Yet these cultural capacities also demand explanation, and many accounts attempting to provide one have appealed to distinctively human cognition. There is certainly evidence to suggest that distinctively human behavioural and cognitive traits function to broaden the scope and accelerate the pace of human cultural evolution. Likewise, cultural learning does appear to play a role in human cognitive development. Most mainstream accounts of human distinctiveness therefore now emphasise coevolutionary interactions between cognition and culture. However, without substantial evidence for the mechanistic details involved in the implied positive feedback process, these accounts remain relatively speculative. Here I discuss work by my own group investigating mutually reinforcing effects of human cognition and cultural learning. I also discuss how Sociocultural EvoDevo Theory could offer a framework for further specifying the detail of the interdependencies between cognition and culture.

**Michael TOMASELLO**

Duke University

**Cultural Coordination and Uniquely Human Cognition**

Human culture has a number of unique characteristics. Some of them involve cultural transmission. But just as important is cultural coordination. Humans are specifically adapted to coordinate actions and attention with others in shared agencies, involving social-cognitive skills such as dual-level collaboration, joint attention, and cooperative/conventional communication. These uniquely human adaptations can be clearly seen in experiments comparing great apes and human children.

**Ehud LAMM**

Tel Aviv University

**Collective Knowledge or Collective Inheritance?**

Cultural Evolution theory is based on an analogy between genetic inheritance and social learning. This led to great insights but also misses important collective phenomena in human cultural evolution. I will distinguish between two aspects of the prevailing paradigm, (1) that learning is individual-to-individual and (2) that cumulative culture requires high-fidelity copying or imitation (like genetic inheritance). I discuss challenges and alternatives to this paradigm that have been suggested to this paradigm. I will then consider one approach to cultural adaptation that transcends individual-to-individual high-fidelity copying based social learning – the notion of Distributed Adaptation (DA), in which knowledge is stored at the group level. I will highlight the collective phenomena that DA attempts to describe and present the potential avenues for understanding their evolution. This will allow me to develop the question whether Niche Construction is a sufficient lens through which to understand the evolution of DAs and how this relates to questions about the phenotypic inheritance, collective inheritance, and the necessity of lineages.

**Oded RECHAVI**

Tel Aviv University

**Thinking Transgenerational Inheritance**

In *C. elegans* nematodes, dedicated machinery enables transmission of small RNAs which regulate gene expression across multiple generations, independently of changes to the DNA sequence. I will discuss new insights regarding the underlying mechanisms, the involvement of chromatin modifications, and the potential of RNAi inheritance to affect the worms' fate. Lastly, I will examine how these new findings might affect our view of the process of evolution and the limits of inheritance and provide evidence that transgenerational inheritance of small RNAs is possible even in other, very different organisms.

**Isabelle M. MANSUY**

University and ETH Zürich

**How Traumatic Experiences in Early Life Can Affect Descendants via the Germline**

Behavior and physiology in mammals are strongly influenced by life experiences, particularly experiences in childhood. While positive factors favor proper development and good mental and physical health in adulthood, early life adversity and traumatic events increase the risk for psychiatric, metabolic and autoimmune diseases and cancer. Such disorders can affect directly exposed individuals but also their descendants and in some cases across several generations. The biological mechanisms underlying the inheritance of environmentally-induced (acquired) traits are thought to involve factors independent from the DNA sequence in the germline. To study these mechanisms, we developed a mouse model of postnatal stress that induces trauma symptoms across generations[1–3]. The symptoms include increased risk-taking, depressive-like behaviors, cognitive and social deficits, as well as metabolic and cardiovascular dysfunctions in adulthood that persist across life in exposed animals. Further, some symptoms are also manifested by the offspring of exposed individuals, up to the 5$^{th}$ generation i.e., risk-taking behaviors[4]. In humans, comparable symptoms affect people exposed to childhood trauma, suggesting conserved effects across species[5]. At a molecular level, exposure is associated with epigenetic changes involving RNA and DNA methylation in somatic cells across the body and in germ cells, with sperm RNA being causally linked to symptoms transmission[2]. MiRNAs are also affected in extracellular vesicles in blood and the reproductive tract[6]. Circulating factors were identified as mediators of some of the alterations in germ cells. Chronic injection of serum from trauma-exposed mouse males into control males recapitulates metabolic phenotypes in the offspring, suggesting information transfer from serum to germ cells. Pathways involving peroxisome proliferator-activated receptor (PPAR) are causally involved, with pharmacological PPAR activation *in vivo* affecting sperm transcriptome and metabolic functions in the offspring and grand-offspring[5]. These results suggest the existence of an ensemble of factors and mechanisms that can carry information about past experiences from the periphery to germ cells for the inheritance of acquired traits[7, 8].

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**Barbara FISCHER**

University of Vienna & Konrad Lorenz Institute for Evolution and Cognition Research

**Modelling the Evolution of Sensitive Windows in Animal Development**

In this talk, I will present an overview of the evolution of plastic windows in animal development. Plastic adjustment of animal phenotypes can involve morphological modifications, adaptations of physiological and neural regulation, or behavioral changes. A famous example of morphological plasticity is, for example, the water flea, *Daphnia* sp., with individuals adapting by growing a protective helmet-like structure in response to the presence of predators in the water. Phenotypic plasticity is sometimes strictly limited to a period in early life, but in other species and traits, it can also be a life-long capacity. I will discuss the environmental conditions that have been understood to lead to the evolution of windows of plasticity of varying length. I will then draw a parallel between these results from evolutionary life-history theory and Bayesian brain theory in human cognitive science, which considers the brain as a statistical organ of inference, able to predict current and future events on the basis of past experiences.

**Claudia BUSS**

Charité – Universitätsmedizin Berlin

**Intergenerational Transmission of Maternal Childhood Maltreatment and the Role of Fetal Programming**

The origins of alterations in brain anatomy and connectivity, that may underlie cognitive impairment and mental illness, can be traced back to the fetal period of life when the developing embryo/fetus responds to suboptimal conditions during critical periods of brain development ("Fetal Programming"). Maternal stress is one such condition that can alter fetal brain development via stress-associated changes in maternal-placental-fetal endocrine (e.g., increases in cortisol concentrations) and immune (e.g., increases in pro-inflammatory cytokines) stress biology. These neurodevelopmental adaptations are possible due to the high degree of neuroplasticity in early life.

Evidence will be presented in support of maternal stress she experienced during her own childhood being associated with alterations in her offspring's mental and somatic health and brain development. Associations between maternal childhood maltreatment and variation in maternal-placental-fetal stress biology suggest them being likely biological mediators that provide cues about her early life stress to the fetus with the potential of altering its developmental trajectory.

Advances in theory and methodology now afford an unprecedented opportunity to gain new and valuable insights into early life environmental conditions affecting brain plasticity and to develop targeted interventions to break the cycle of intergenerational transmission and to support healthy development.

**Annelies HOORN**

University of Toronto

**Temporal Dynamics of Neuronal Excitability in the Lateral Amygdala Mediates Allocation to an Engram Supporting Conditioned Fear Memory**

Memories are stored in ensembles of neurons called engrams, which are active during learning. In the lateral amygdala (LA), associated with fear memories, neurons with elevated excitability during training are more likely to contribute to engram formation. We examined the temporal dynamics of neuronal excitability crucial for memory allocation using calcium imaging in freely moving mice undergoing Pavlovian fear conditioning. Neurons active up to 6 hours prior to learning show a high reactivation rate during the test, suggesting that these neurons are important in encoding the memory. To examine the functional role of this increased excitability on memory allocation, we used an optogenetic approach, by activating a small subset of LA neurons before fear conditioning, biasing engram allocation up to 6 hours before training. These findings highlight the temporal specificity of excitability in the LA and its pivotal role in selecting which neurons become part of a memory engram.

**Regina M. SULLIVAN**

New York University School of Medicine & Nathan Kline Institute for Psychiatric Research

**Mechanisms of Neurobehavioral Intergenerational Transmission of Infant Attachment and Trauma**

Children, and the young of other altricial species, require parental care for survival and bi-directional attachment provides a social framework for this care. For infants, this is a robust system where survival is dependent upon quickly learning the attachment figure and emitting prosocial behaviors that elicit caregiving, regardless of the quality of caregiving. However, the quality of care lays the roots of pathology as it covertly programs the brain for later-life behavior. While we know the later-life impact of caregiving, we have little understanding of how the infant brain processes parental care or how it initiates the pathway to pathology. Here, using infant rodent prosocial behavior to nurturing and adverse parental care, we present data suggesting the infants amygdala processing of the safety signal value of the parent is the source of aberrant infant social behavior. Furthermore, increased stress hormones within a social context of the parent appears to initiate the process of devaluing the maternal safety signal but also its repair. Together these data suggest cross-species translational value and the importance of the social context of trauma as defining the developmental trajectory.

**Francesca CIRULLI**

Istituto Superiore di Sanità / Italian Institute of Health

**Embedding Early Experiences into Brain Function: Understanding the Neurobiological Mechanisms to Improve Resilience in the Face of Adversity and Build the Foundation of a Healthy Life**

Early stressful experiences can hinder brain maturation and increase individual vulnerability for psychopathology. Epigenetic “embedding” of early life adversity represents a fundamental mechanism to adapt the individual to the “ecological niche” by promoting short and long-term changes in biomarkers and neurochemical pathways, ultimately affecting brain function. Epigenetic changes may determine constitutive modifications of gene expression, as well as alter context- and time-dependent gene expression responses at later time points, potentially increasing likelihood to develop psychiatric disorders. We will explore these “embedding” mechanisms from a neurobiological perspective showing how stressful experiences as well as unhealthy diets can have similarly effects on adult brain function, potentially impinging upon evolutionarily conserved pathways. Overall, these mechanisms can be viewed as part of the cultural neurobiological inheritance system (CNIS) responsible for passing to the subsequent generations changes in socio-emotional and cognitive function resulting from adverse experiences. Understanding these mechanisms can be fundamental to improve resilience in the face of adversity.

**Igor BRANCHI**

Istituto Superiore di Sanità / Italian Institute of Health

**Uncovering the Determinants of Brain Functioning, Behavior and Their Interplay in the Light of Context**

Notwithstanding the huge progress in molecular and cellular neuroscience, our ability to understand brain and behavior is still limited. This can be partially ascribed to the reductionist, deterministic and mechanistic approaches that struggle with the complexity of the central nervous system. The aim of my contribution is to introduce the *Context theory of constrained systems* that entails key conceptual implications: (i) context is the main driver of behavior and mental states; (ii) substrates, from genes to brain areas, have no direct causal link to complex behavioral responses; (iii) context and biological substrates play distinct roles in determining behavior: context drives behavior, substrates constrain the behavioral repertoire that can be implemented; (iv) since behavior is the interface between the central nervous system and the environment, it is a privileged level of control of brain functioning. This theoretical framework calls for the revision of key concepts in neuroscience and psychiatry, including causality, specificity and individuality.

**Eörs SZATHMÁRY**

Parmenides Foundation & Eötvös Loránd University

**Darwinian Neurodynamics: True Evolution on the Millisecond Scale?**

Evolution and learning are both producing adaptive solutions. Traditionally, evolution is associated with transgenerational population dynamics and learning happens withing the lifetime of individuals. Recently, researchers are asking two, related questions: how much of evolution is better understood in terms of learning theory and, conversely, what aspect of learning may be realized by intracerebral evolutionary dynamics. Darwinian neurodynamics seeks to elucidate the second problem. Perhaps the most exciting approach investigates how candidate solutions to complex combinatorial problems could be solved by evolutionary search in a population of candidate solutions that can multiply and show hereditary variation.

**Antonella TRAMACERE**

University of Roma Tre

**Scaling Up Embodied Perspectives in Cognitive Evolution**

Studies on cognitive evolution are still steeped in explanations based on the concept of domain-specificity and assume that the cognitive traits on which natural selection has acted must have a specific internal neurobiological structure. This is problematic because it is based on a science of the mind that is losing ground to more viable alternatives. The latter are the embodied approaches, which question the existence of fixed, internally structured, and isolable representations in the development of cognition.

Domain-specific explanations of cognitive evolution also led to an oversimplification of the interaction between biology and the (social) environment and, finally, to a misrepresentation of the role of culture in producing changes during human evolution.

I will illustrate an alternative view, based on the concepts of *genetic accommodation* and neuro*epigenetic homologies*, and contextualize it in an embodied framework for the study of the evolution of the mind.

**Adam LINSON**

Open University

**Cultural Pressure on the Evolution of Cognitive Flexibility: Polyvalent Perception, Context Modulation, and Planning as Inference**

This contribution will focus on a potential role of early music and dance in Cultural Neurobiological Inheritance Systems related to cognitive flexibility. There are likely to be many neurobiological requirements for music and dance to arise as part of human culture. Yet it is plausible that, once established, some of these cultural practices could place demands on functional neurodynamics. If sustained in a cultural niche, those demands could exert influence on the heritability of factors in enhanced cognitive flexibility. While almost nothing is known about prehistoric music and dance, some ancient music and dance that is indicative of cognitive flexibility remains sociohistorically connected to present-day cultural practices. The establishment and maintenance of these and related cultural practices in humans globally suggests a set of intersections and feedback loops associated with the Extended Evolutionary Synthesis. The above considerations provide an alternative to conventional accounts of the origins of music and dance.

## Notes

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