# SESSION SCHEDULE

# "EVOLUTION OF CULTURE COMPLEXITY"

September, 21$^{st}$ (9:00 – 18:30)

**9:00 - 9:20  OPENING**

**SESSION 1   SOCIAL CONSTRUCTION OF CULTURAL COMPLEXITY**

9:20 - 10:00 Keynote speaker **Tom Froese**

10:00 - 10:25

Global information and consensus formation: theory and simulation

Francesca Lipari (Lumsa University)

Brais Alvarez-Pereira (European University Institute)

Alireza Goudarzi (Laboratory for Neural Computation and Adaptation)

Leonhard Horstmeyer (Max Planck Institute for Mathematics in the Sciences)

**10:30 - 11:00   COFFEE BREAK**

11:00 - 11:25

Could complex referential communication emerge without innate grammar or

intergenerational transmission?

Jorge I. Campos (4E CognitionGroup, Instituto de Investigación en Matemáticas Aplicadas y Sistemas, UNAM)

Tom Froese (4E CognitionGroup, Instituto de Investigación en Matemáticas Aplicadas y Sistemas, UNAM)

11:25 - 11:50

Dynamic social conflict in the Axelrod model

Carlos Gracia-Lázaro (Instituto de Biocomputación y Física de Sistemas Complejos, Universidad de Zaragoza)

Alexis R Hernández (Instituto de Física, Universidade Federal do Rio de Janeiro)

Edgardo Brigatti (Instituto de Física, Universidade Federal do Rio de Janeiro)

Yamir Moreno (Instituto de Biocomputación y Física de Sistemas Complejos, Universidad de Zaragoza)

**SESSION 2   MODEL OF EVOLUTION OF CULTURE**

11:50 - 12:30 Keynote speaker  **Sergi Valverde**

12:30 - 12:55

Global knowledge dynamics in computationally assisted, complex cultural networks

Thomas Petzold  (HMKW Berlin)

**13:00 - 14:30   LUNCH TIME**

14:30 - 14:55

A Review and Critique of Gabora's Models of Cultural Evolution

Mario A. Zarco-López (IIMAS-UNAM)

Tom Froese (IIMAS-UNAM)

## SESSION 3   ARCHAEOLOGICAL EVIDENCE OF CULTURAL COMPLEXITY

**14:55 - 15:35** Keynote speaker  **Alex Bentley**

**15:35- 16:00**

Digging for Patterns in Cave Art Marks through Symmetry Operations

Emre Kaya (Bogazici University)

## 16:00 - 16:30   COFFEE BREAK

**16:30 - 16:55**

The role of migration in the evolution of behavioural plasticity

Iza Romanowska (Barcelona Supercomputing Center)

Seth Bullock (University of Bristol)

**16:55 - 17:20**

Complexity matters: Uncovering mechanisms of social complexity in the past

Dries Daems (University of Leuven)

**17:20 - 17:45**

Long-term trends in the Roman imperial economic system: experiments on amphora

recycling and product preference

Tom Brughmans (University of Oxford)

## 17:45 - 18:30   DISCUSSION

**19:00  WELCOME COCKTAIL**


## ORGANIZING COMMITTEE

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## SESSION 1   SOCIAL CONSTRUCTION OF CULTURAL COMPLEXITY

## Can cultural complexity emerge via collective ritual?  The case of ancient Teotihuacan

Tom Froese (IIMAS,  Center for Complexity Sciences (C3), UNAM)

Experts remain divided about the nature of the sociopolitical system of ancient Teotihuacan, which was one of the earliest and largest urban civilizations of the Americas. Excavations hoping to find compelling evidence of powerful rulers, such as a royal tomb, keep coming away empty-handed. But the alternative possibility of a corporate or collective government still remains poorly understood. There is a lack of evidence of a powerful bureaucracy, but a decentralized network limited to the level of neighborhood representatives seems susceptible to problems of collective action. Previously we used a computational model to show that in principle this latter worry is unfounded, as long as we assume that the network's topology could be transformed via community rituals and was not strongly subdivided (Froese, Gershenson, and Manzanilla 2014). Here we extended this model to investigate whether increased social hierarchy could mitigate the negative effects of strong divisions. We found a special synergy between hierarchy and community ritual in that only their combination improved the extent of cooperation, which is consistent with portrayals of the elite as religious specialists serving the public good.

## Global information and consensus formation: theory and simulation

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Understanding the mechanism of social learning is important in an uncertain and complex world in which, as Hayek said, knowledge of the circumstances is never presented in concentrated or integrated form, but rather as "dispersed bits of incomplete and frequently contradictory knowledge which all the separate individual posses". Agents can rely on two mechanism of information aggregation, a local mechanism and global one. The first comes directly from individual interaction with their peers and neighbors on an ongoing basis. The second is displayed by policy intervention. Sometimes, these two mechanisms are in disagreement, some other times they reinforce each other on a particular issue, ultimately their interaction is important to understand the dynamics of agents' opinion about social issues (i.e. vaccines, gender norms, political participation etc).

In this work our aim is twofold. We study, first, the learning mechanism that produces the emergence of new opinion and, in it, what is the role of the two forms of information aggregation in shaping the mechanism of opinion and consensus formation; second, we study how the new opinion is endorse. We model a collection of interacting agents endowed with an initial multi-attribute identity and initial opinions over those attributes. The dispositions evolve over time in a social learning process, through exposure to local and external information. The model allows us to study how fast consensus is reached in this learning environment as a function of the strength of the external information and the divergence between agents' individual disposition and the established norms.

## Could complex referential communication emerge without innate grammar or intergenerational transmission?

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**Keywords:** referential communication, evolution of language, iterated learning model, collective intentionality

Tomasello (2014) proposes a thought experiment inspired by Lord of the Flies: what would happen if a group of human infants grew up together in isolation? Tomasello argues that the infants could develop forms of joint intentionality during their lifetime (including communicating via pointing), but that forms of collective intentionality involving normative practices (including communicating via language) would only start to emerge over multiple generations as ontogeny becomes shaped by an increasingly complex

sociocultural context. In contrast, groups of infant chimpanzees would not be able to develop either of these forms of sociality. This argument is based on two assumptions: (1) specifically human biology is necessary but not sufficient for the emergence of normative sociocultural practices, because (2) it is also necessary for humans to establish the required conventions over multiple generations. We probe both of these assumptions on the basis of a variation of the iterated learning model (ILM) of language evolution (Kirby and Hurford 2002). The results of our model allow us to suggest that (1) conventions resembling properties of language can emerge during repeated social interactions during a single generation's lifetime, and (2) that this process does not depend on specificities of the learning agent's cognitive structures. Nevertheless, a problem of initial conditions remains, in particular as sufficiently long and arbitrarily varied utterances are required for the ILM to work properly, and this is where biological and cultural intergenerational transmission may indeed play an essential role (Merker and Okanoya 2007).

## Dynamic social conflict in the Axelrod model

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In the Axelrod's model of dissemination of culture, we consider the incorporation of new topics into the social debate as an agreement is reached in other topics, modeling this situation through the initialization of the topics in which a consensus has been reached. When the fraction of agents sharing the most abundant trait of a topic reaches a threshold, consensus on the topic is assumed and it is replaced by a new emerging topic through the initialization o traits in that topic.

As an additional modification, we consider two mechanisms: homophily and aversion. If the cultural overlap between two agents is higher than a given threshold, the culture of one of those agents is allowed to change by imitation of an uncommon topic's trait, with a probability proportional the overlap. Otherwise, individuals will be able to discern about

common trait: the smaller the overlap, the greater the rate of unimitation.

Our results show that once cultural groups are consolidated, the emergence of new themes in the social debate does not have a significant effect on them, but it does on cultural overlaps. We find conditions for stationary partial multiculturality, as well as a transition that exhibits the characteristic bimodal character of a discontinuous transition. In addition, we show that aversion minimizes the cultural overlap.

## SESSION 2   GENERAL MODEL TO UNDERSTAND CULTURAL COMPLEXITY

### Major Transitions in Information Technology

Sergi Valverde (Universitat Pompeu Fabra)

When looking at the history of technology, we can see that all inventions are not of equal importance. Only a few technologies have the potential to start a new branching series (specifically, by increasing diversity), have a lasting impact in human life, and ultimately become turning points.

Technological transitions correspond to times and places in the past when a large number of novel artifact forms or behaviors appeared together or in rapid succession. Why does that happen? Is technological change continuous and gradual, or does it occur in sudden leaps and bounds? The evolution of information technology (IT) allows for a quantitative and theoretical approach to study technological transitions.

The coexistence of episodes of gradual improvements and discontinuous technological change is a consequence of the asymmetric relationship between complexity and hardware and software. Using a cultural evolution approach, we suggest that sudden changes in the organization of information technology systems depend on the high costs of maintaining and transmitting reliable information.

### Increasing complexity: steps in the (chrono)logic of cultural evolution

Barend van Heusden (University of Groningen)
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One way in which we might be able to account for the evolution of cultural complexity is by showing that his complexity can result from a relatively simple process structure. In my paper, I will argue that the structure of the cognitive process underlying human culture is both cumulative and recursive and by being so, generates increasing complexity, on the basis of a restricted number of relatively simple (cognitive)building blocks.

Human culture emerged in primate evolution when our ancestors became aware of a difference between the past and present, between a relatively stable set of memories and a changing actuality ('decoupling'). The necessity to deal with this difference, and to relate past and present, generated and still generates culture. Moreover, as the process itself could now be stored in memory and therefore also recognized in actuality, it became necessarily recursive.

The number of cognitive strategies that can be used to bridge the gap is limited, and they build upon each other: it involves, first, the perception of similarities, then the imagination, followed by conceptualization through language and, finally, the analysis of underlying structures through graphic symbols. Each time a new strategy came into being, it first went through an adaptation of all the strategies already present, before coming 'into its own'. In combination with the recursive character of cultural cognition, this may have caused growing levels of complexity, coming about at an ever increasing speed.

## Global knowledge dynamics in computationally assisted, complex cultural networks

Thomas Petzold  (HMKW Berlin)
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This paper presents the concept of knowledgebits, which extends on mainstream working models about evolutionary knowledge growth (e.g., see Hayek, 1945; Popper, 1963; Boulding, 1977; Arthur, 2009), as well as more recent advances at the intersection of culture and computation (e.g., see Hidalgo, 2014; Hartley & Potts, 2014; Bentley & O'Brien 2017). The concept of knowledgebits contributes towards a better understanding of the dynamics of sociocultural complexity by providing a framework that assesses the combinability (combination + compatibility) of the world's knowledge in our computationally assisted, complex cultural networks. It starts from the assumption that every individual disposes of an ever-changing set of entities of knowledge as each person

internalises and externalises by using human and artificial assistance. The concept of knowledgebits is grounded in empirical evidence derived from both largescale digital network analysis as well as individual case studies research about how various bits of knowledge from a diverse range of languages may combine (Petzold, 2017). It allows to tackle questions such as what bits of knowledge are more likely to survive, or how fast knowledgebits may spread. Overall, the paper contributes to the satellite's anticipated efforts by providing a conceptual harbinger that helps to explain the global propagation and loss of cultural complexity in our computationally assisted, complex cultural world.

## A Review and Critique of Gabora's Models of Cultural Evolution

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**Keywords:** Computational model of cultural evolution, Agent-based model, Neural network based agents, Liane Gabora, Material engagement, Embodied model for cultural evolution

Liane Gabora developed a computational model of cultural evolution named MAV (Meme And Variations) (Gabora 1995), which she later extended into a model called EVOC (EVOlution of Culture) (Gabora 2008b). The models simulate neural network based agents with an array-based body in a grid-cell world. Agents generate ideas for body configurations, or they copy them from their neighbors, depending on the relative fitness of the ideas. The simulations are motivated by her theory that internal models of the world are the units of culture that evolve (Gabora 1995). Ideas and artifacts are treated as merely the external reflection of the evolved state of an internal worldview, and they are expressed in the behavior of agents. We highlight a tension between treating behavior as an epiphenomenon and the growing recognition in cognitive archaeology of the constitutive role of material engagement (Malafouris 2013). As a consequence, we criticize the internalist view of mind adopted by Gabora. Moreover, we point out concerns with the fact that these models reduce the dynamics of cultural complexification to an evolutionary process based on fitness, even though Gabora argues that her culture evolution theory is non-Darwinian (Gabora 2008a). Also, we note technical problems related to the way her theory is implemented in the simulations. Finally, we conclude that her attempt of introducing an embodied model for cultural evolution is pointing in the right direction, but

unfortunately falls short of its ambitious goal because the models become processes of learning and transmission of information using isolated neural networks.

## The acceleration of cultural change - from ancestors to algorithms

Alex Bentley (University of Tennessee)

Millennia, sociocultural complexity increased (and occasionally decreased) gradually over many human generations, as people inherited traditional knowledge within kin-based local communities. In these settings, where knowledge was shared within populations and across generations, socio-technological complexity tended to scale with population size. In the 21st century, however, knowledge is transmitted across populations and within generations — sociocultural complexity may not scale with population size in the way it had before. To span these different scales and modes of cultural evolution, different representations are useful, including fitness landscapes and a heuristic representing the transparency of payoffs in social learning. I will use these approaches to discuss how cultural evolution may have profoundly changed — as a process — from prehistoric societies to mass/social media and future artificial intelligence.

## Digging for Patterns in Cave Art Marks through Symmetry Operations

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Keywords: Cave Art, Upper Palaeolithic Era, Symmetry operations

Cave art of Upper Palaeolithic Era consists of paintings and engravings made on parietal and portable contexts which are considered to be among the first indicators of human artistic creativity and abstraction. Generally, these works fall into two categories: first category is the figurative art, where animals of various kind are depicted, and second is the non-figurative art, consisting of geometric and abstract marks. Although figurative art is thoroughly studied and attempted to explain, non-figurative art lacks these efforts and is yet to be examined.

This study is an attempt to provide insights into non-figurative marks. Considered as purely geometric entities, these marks are observed to indicate inter-and intra-regularities.

Exploring these patterns is a way of understanding the marks without necessarily trying to interpret them or assuming that they have representational purposes. In this study, 90 of these marks found in Upper Palaeolithic caves worldwide, but more concentrated on Northern Spain and Southern France, are analysed through their photographs. The marks are investigated according to presence or absence of five symmetry operations possible in plane, i.e. translation, horizontal and vertical reflection, glade reflection and rotation. Distribution of symmetry operations present within the marks, together with their distribution among different time periods will be the main outcome of this study. Moreover, these results will be used to further answer whether there exists correlation between temporal distribution of different symmetry operations and cultural complexity, and thus whether complexity of the marks can be considered as a sign of evolution in cultural complexity.

## The role of migration in the evolution of behavioural plasticity

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Human migration events have been a major focus of archaeological research in the last 50 years. However, despite extensive research, many of the key questions related to this topic remain unanswered. The study presented here looks at the relationships between climate change, migration and the evolution of behavioural plasticity using a formal computational framework. It is based on the Variability Selection Hypothesis proposed by Potts (1996) and formalised by Grove (2011), which concerns the evolution of versatility among human groups arising during periods of strong environmental fluctuations. The model was translated into a stochastic agent-based simulation to investigate the dynamics between individuals with different adaptations (including 'versatilist' individuals) within a heterogenous population. The results show that dispersal accelerates the evolution of versatilism in the population, therefore promoting a more flexible and robust range of adaptations. It also demonstrates the particularity of natural selection conditions at the front of a dispersal wave and at the core area from which individual migrate. Such conditions enable the evolution of adaptations beneficial in the long turn but not optimal at any one point in time thus highlighting the role of events which keep populations below their full capacity. Potts, R. 1996. Evolution and Climate Variability. Science 273: 922–23. Grove, M. 2011. Speciation, diversity, and Mode 1 technologies: The impact of variability selection. J Hum Evol 61: 306–19.

# Complexity matters: Uncovering mechanisms of social complexity in the past

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**Keywords:** social complexity, socio-political organisation, Sagalassos, complexity archaeology

In archaeology, social complexity has long been considered within an evolutionary discourse of fixed stages of increasingly complex societies. In recent years, another approach has started to gain tract, studying complex societies starting from the more general phenomenon of complex adaptive systems (CAS). Too often however, complexity approaches in archaeology have been used merely on a metaphorical level, hardly taking into account why and how complexity in human societies arises. If archaeologists are ever to move beyond the level of metaphor, we need to uncover the underlying mechanisms of social complexity.

CAS are open systems, requiring constant external energy input to maintain its internal structures, transforming energy into exergy, or useful energy. As a general property, self-organizing dissipative processes arise in complex systems whenever sufficient exergy is available to sustain them. Social systems are different from other complex systems through the factor of human agency. Still, given sufficient exergy input from their environment, increasingly complex configurations commonly develop. This process can be explained through the approach to complexity as a problem-solving tool. A social system develops solutions to internal and external disturbance events through development of its social, political, economic, and ideological structures. Complex social systems develop as independent components become increasingly interrelated within nested hierarchies of functional, informational, and decision-making roles. In this paper I will further elucidate this development through a case-study based on the development of socio-political organisation in Sagalassos and Düzen Tepe (SW Anatolia) during the late Achaemenid and Hellenistic periods (5th to 2nd centuries BCE).


# Long-term trends in the Roman imperial economic system: experiments on amphora recycling and product preference

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**Keywords:** archaeology, history, economy


In this presentation I will explore long-term change in Roman amphorae distributions caused by recycling and consumer preference, contributing to a better understanding of long-term trends in a particular socio-cultural system: the Roman Empire. What kinds of empire-wide distribution patterns of amphorae would we expect to see if we assume amphorae might have been recycled as containers to transport different types of goods? How does an individual's or a community's preference for one type of product over another affect the distribution of both? Are these processes even archaeologically visible: under what conditions do they lead to undeniably

different distribution patterns as compared to processes that exclude these factors? A set of increasingly elaborate computational models will be presented to explore these questions. Particular emphasis will be placed on understanding the effects of the Roman transport network and the demand of urban centres on these processes.

This work is part of the larger research agenda of project MERCURY, a multidisciplinary project that will explore the most hotly debated questions about the Roman economy: was the Roman Imperial trade market equally integrated as nowadays? How important were social networks for structuring this flow of information? It will address two methodological issues currently preventing scholars from answering these questions: limited use of archaeological big data and the lack of quantitative comparisons of complex hypotheses. MERCURY will combine recent advances in computational network science and simulation methods with increasingly available archaeological big datasets.

MERCURY website:
http://oxrep.classics.ox.ac.uk/affiliated%20projects/mercury/