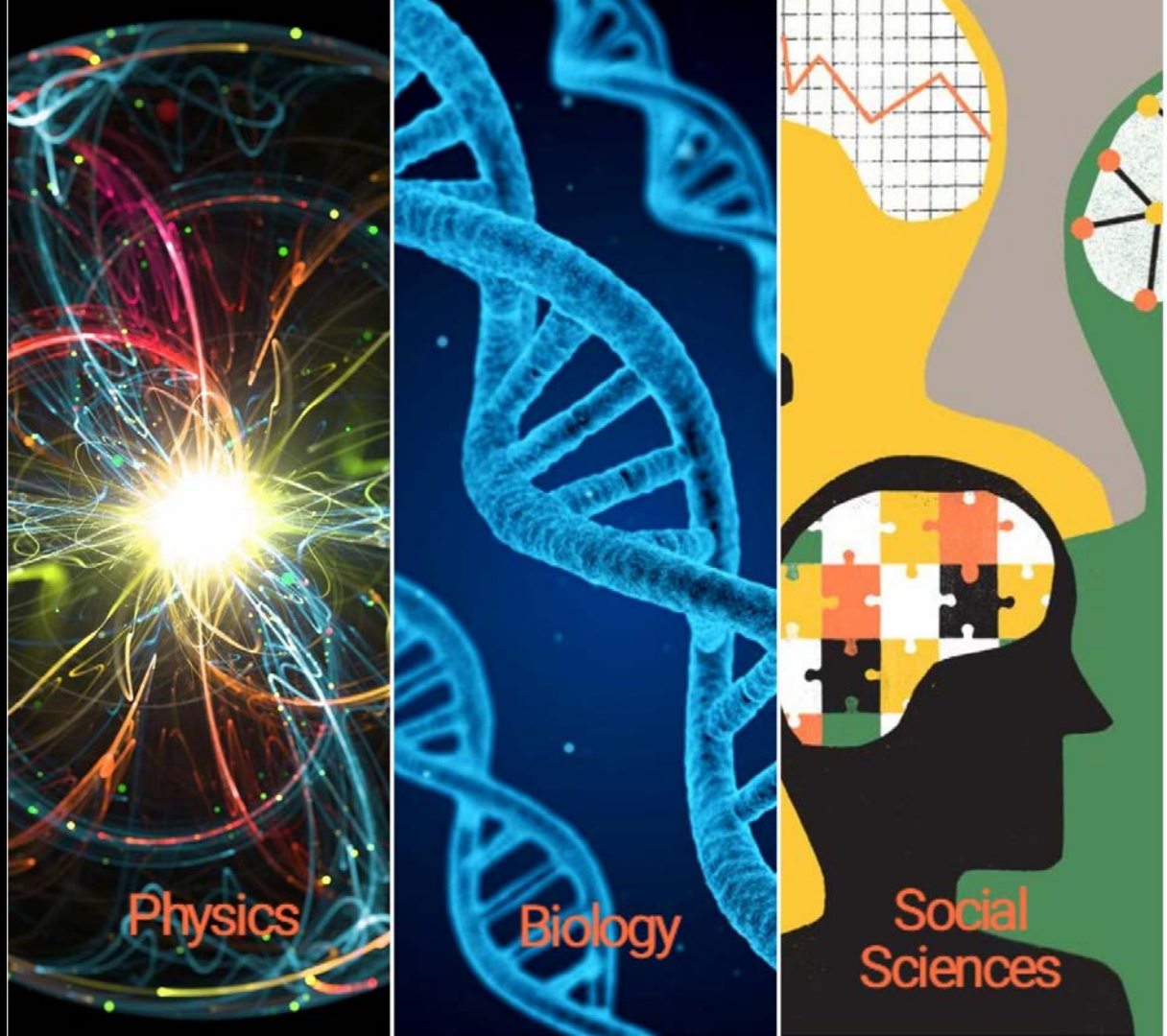
Complex systems Theory

A very brief Introduction

Abstraction of “complexity” from each field



Understanding complex system

Since complex systems are a sort of a mixture between certain fields, then let’s understand the each of their relevant components to the whole of complex systems.

What is physics?

- It is a experimental, predictive, and quantitative science of matter and its interactions.
- Matter ranging from microscopic to macroscopic
- The field mostly relied on analytical solutions so far because the four fundamental forces are:
  - Homogeneous (act in the same way everywhere)
  - Isotropic (act in the same in all direction)
  - Forces differ greatly in strength.

Compare and Contrast

- Goals:
  - Experimentally testable, quantitative, and predictive
- Subject:
  - Physical matter, and their interactions
- Key Assumptions and fact:
  - Homogeneous, isotropic, and force in domain specific
- Analytical

- Goals:
  - Experimentally testable, quantitative, and predictive
- Subject:
  - ‘Generalized’ matter, and their ‘generalized’ interactions
- Key Assumptions and fact:
  - Homogeneous (mostly not), isotropic (mostly not), and interaction can change over time and be s*pecific (*i.e. Not all elements, only certain pairs or groups of elements, interact with each other.)
- Algorithmic

From the physics’ perspective

- Many elements describe by state.
- Elements are not limited to physical forms of matter.
- Interactions may be specific, that is who interacts with whom, when, in what form, and how strong is described by interaction networks

From the physics' perspective cont'

- Interactions are not limited to the four fundamental forces
- May involve superpositions of interactions of similar strengths.
- ***Chaotic***, that is depend strongly on the initial conditions and details of the system.
- Complex systems can exhibit a rich structure and have a huge variety of macrostates that often cannot be inferred from the properties of the elements. (***Emergence***)

The theory of complex systems is the quantitative, predictive and experimentally testable science of generalized matter interacting through generalized interactions.

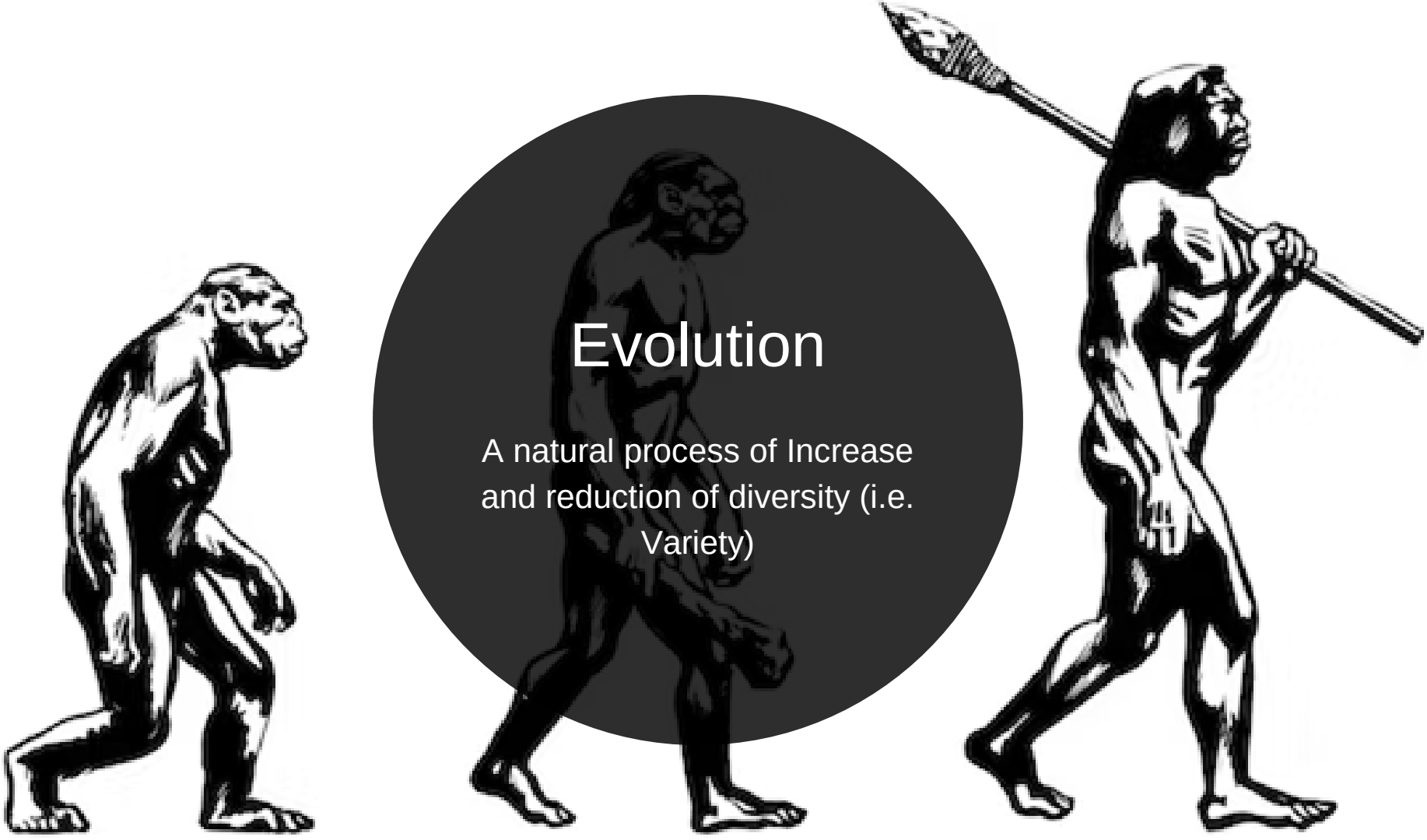
$$M_{ij}^{\alpha}(t)$$

Components of complex systems from Biology

- For many complex systems, the framework of physics is incomplete.
- several key features of complex systems that have been adopted from biology. In particular, we discuss the concepts of **evolution**, **adaptation**, **self-organization**,and, again, networks

Evolution

A natural process of Increase and reduction of diversity (i.e. Variety)



Evolutionary process

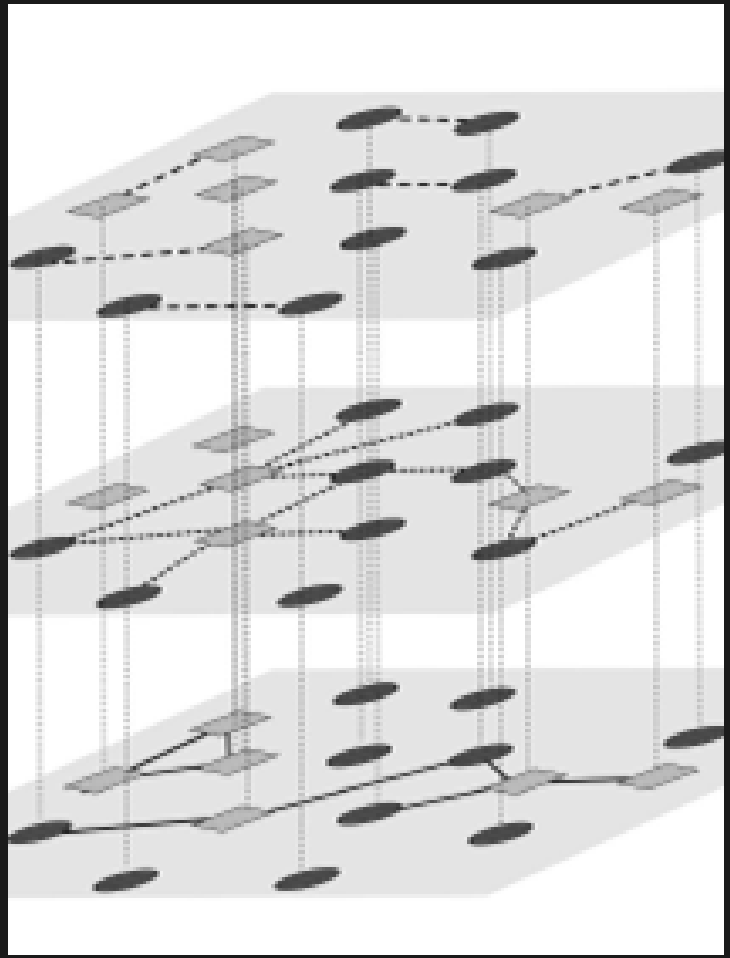
- Three critical components:
  - Replication (Which have several stochastic components
  - Variation
  - Environment (Not fixed, always changing)
- Existence of “Booms”and “Crashes”

Components of complex systems from social sciences

- For many complex systems, the framework of physics is incomplete.
- several key features of complex systems that have been adopted from social science. In particular, we discuss the concepts of **co-evolution**, **multi-layered interactions**, **game theory,** and, again, networks

Multi-layered time varying networks

- Social systems can be thought of as time-varying multilayer (multiplex) networks
- which happen
- Individuals interact through a
- superposition of these different interaction types (multilayer network), simultaneously and are often of the same order of magnitude in ‘strength’.



So.. What are complex systems?

Co-evolving Multi networks.

Facts summary about complex systems

- Complex systems are composed of many elements. These are labelled with indices, i.
- These elements interact with each other through one or more interaction types, we represent with networks. Interactions are links. while elements are the nodes. Every interaction type can be seen as one network layer in a multilayer network.
- Multilayer network can evolve independently or co-evolve
- Interactions are not static but change over time.
- Elements are characterized by states. States can be scalar, it will be described by a state vector or a state tensor. States are not static but evolve with time.
- The dynamics of co-evolving multilayer networks is usually highly non-linear
- Complex systems are context-dependent
- Complex systems are algorithmic
- Emergence

Thank you for your time!