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Email: rocha@binghamton.edu
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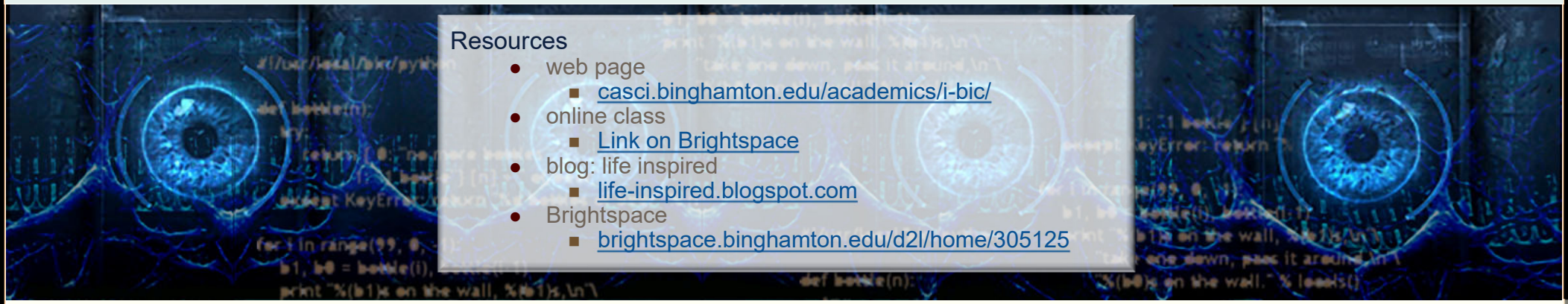
evolutionary systems and biologically-inspired computing



Resources

- web page
  - casci.binghamton.edu/academics/i-bic/
- online class
  - Link on Brightspace
- blog: life inspired
  - life-inspired.blogspot.com
- Brightspace
  - brightspace.binghamton.edu/d2l/home/305125

ISE-483/SSIE-583 - spring 2023

luis m. rocha

office hours:

thursdays 9:00- 11:30am, EB S04

binghamton.zoom.us/my/luismrocha

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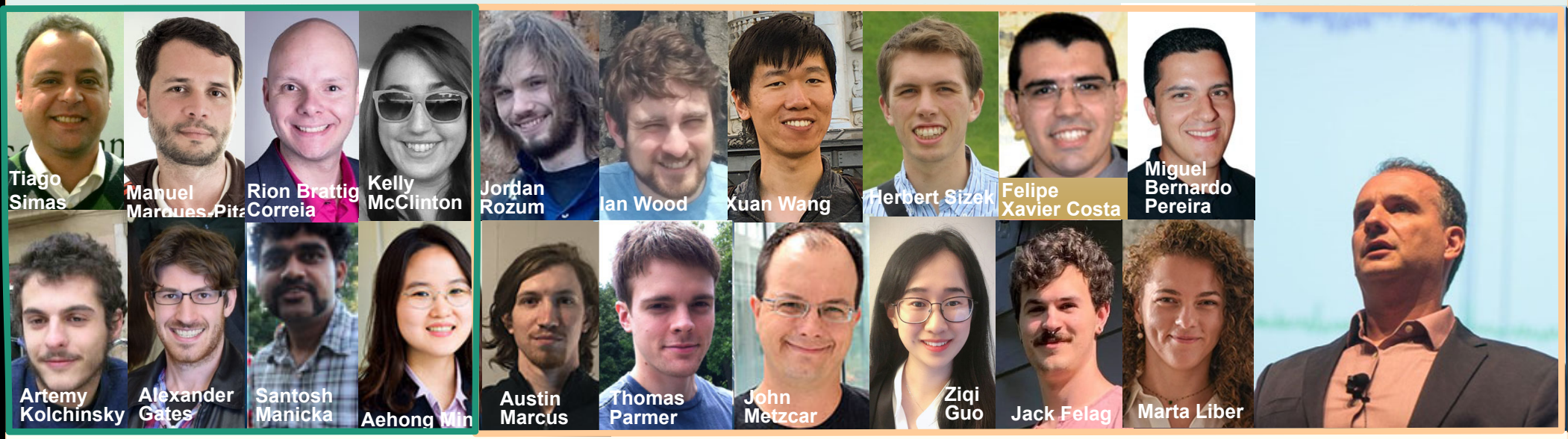
evolutionary systems and bio-inspired computing



what I do

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FULBRIGHT

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

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NSF

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DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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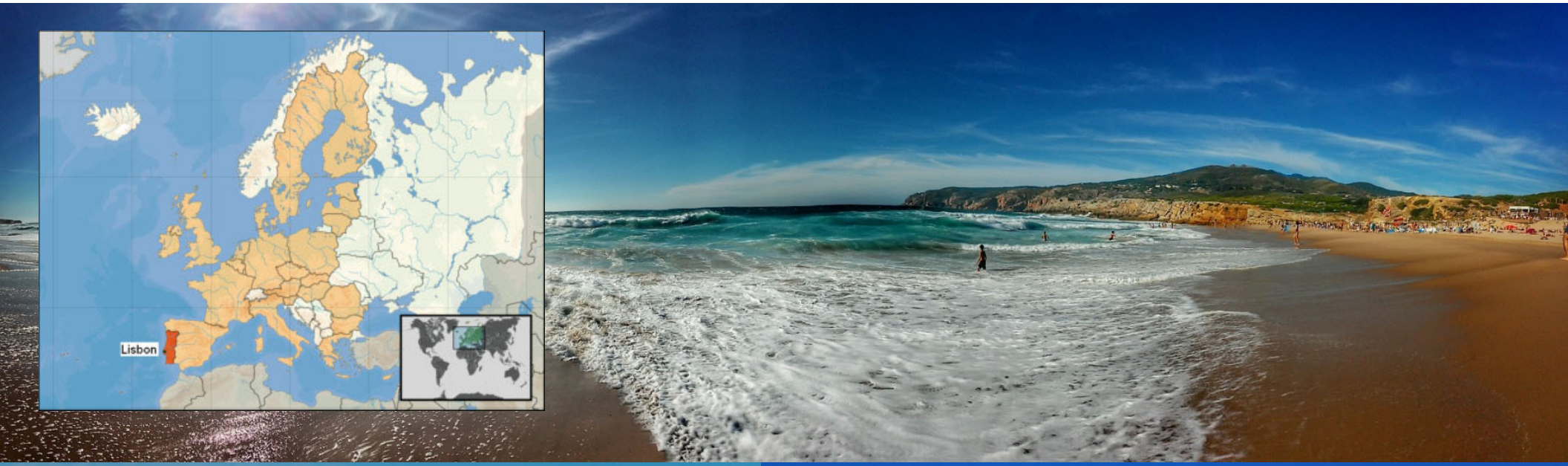
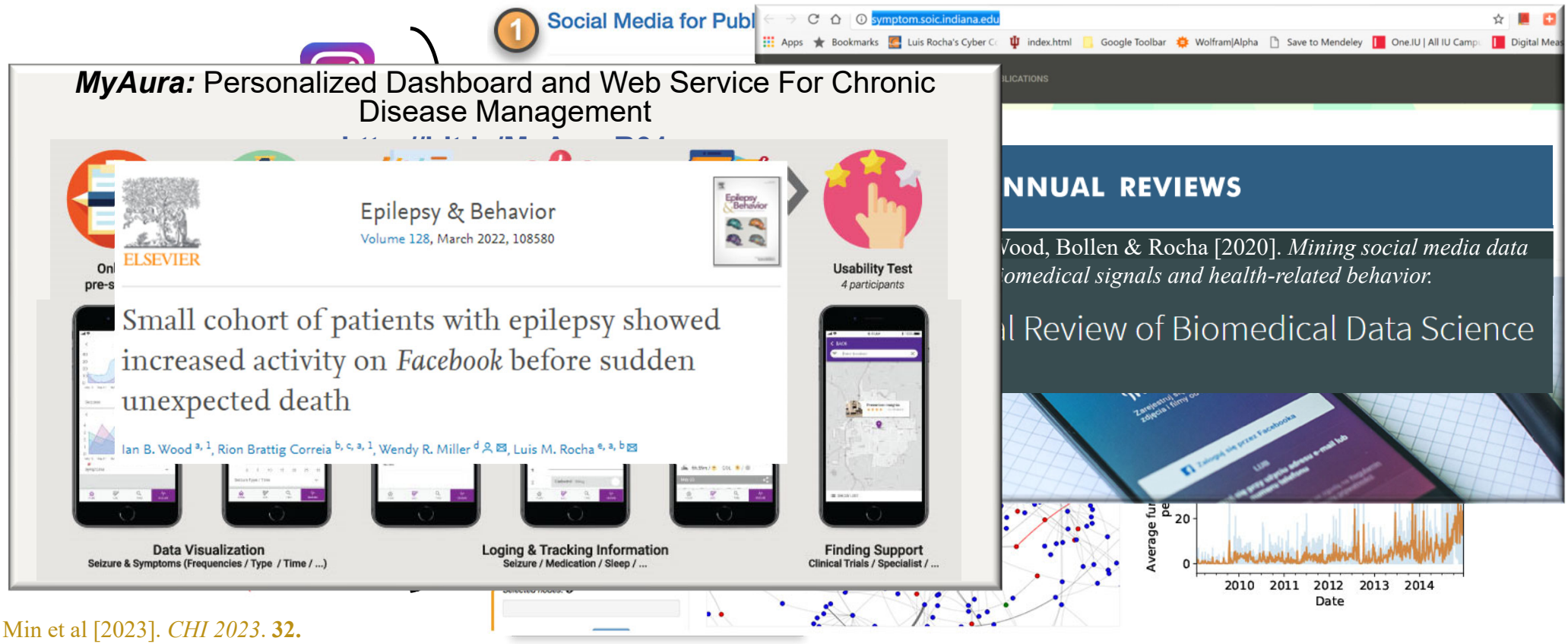
GULBENKIAN SCIENCE


Lisbon


Luanda

social media data pipelines for biomedicine



Min et al [2023]. *CHI 2023*. **32.**

Wood, Correia, Miller, &Rocha [2022]. *Epilepsy & Behavior*. **128**: 108580.

Correia, Wood, Bollen, & Rocha [2020]. *Annual Review of Biomedical Data Science*, 3:1.

Wood, Varela, Bollen, Rocha & Sá [2017]. *Scientific Reports. 7: 17973* .

Correia, Li & Rocha [2016]. *PSB*: **21**:492-503.

Ciampaglia, et al [2015]. *PloS ONE*. **10**(6): e0128193.

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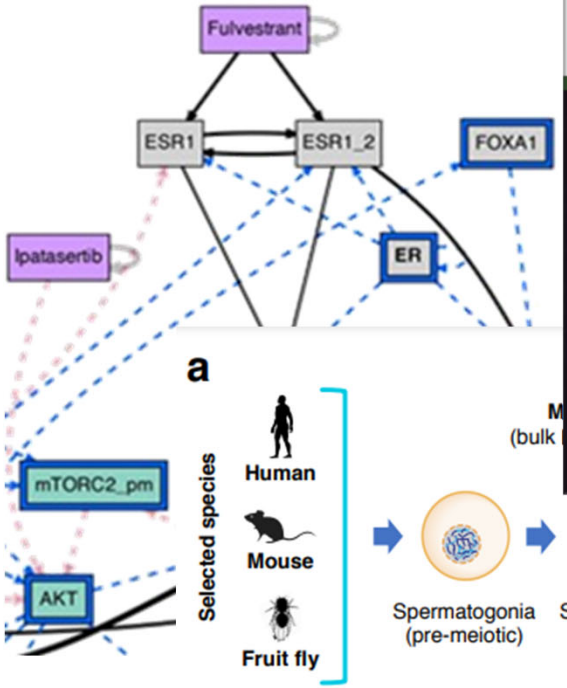
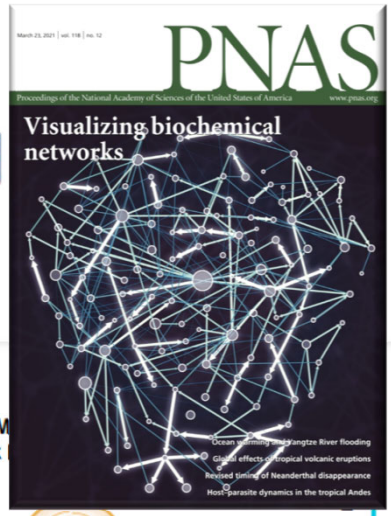
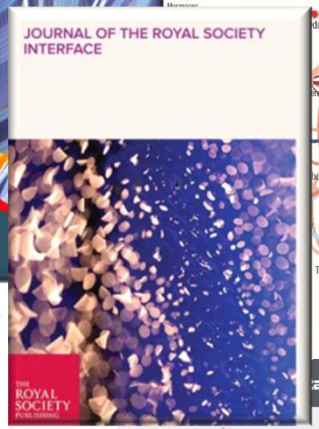
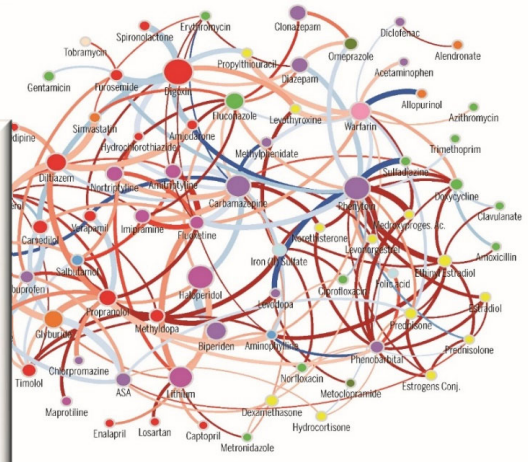
integrating and analyzing multiomic electronic health records with network science

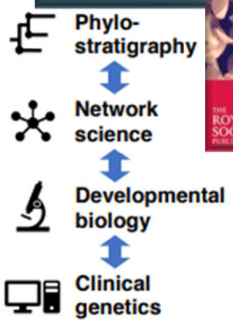
to predict comorbidity & drug interaction networks, disease factors & interventions

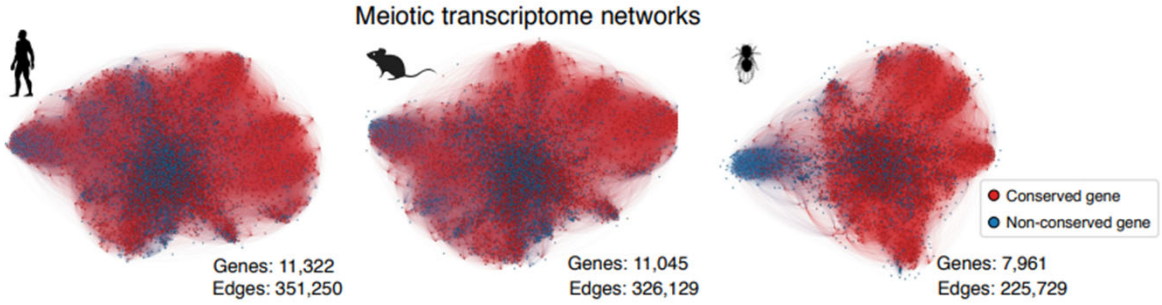












al medicine > articles > article

npj Digital Medicine

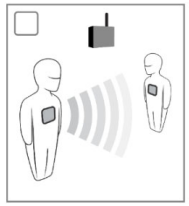
Correia, Araujo, Mattos & Rocha [2019]. **2**:*74*.

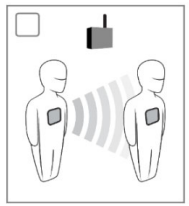
Article | Open Access | Published: 23 July 2019

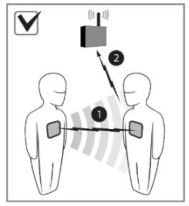
City-wide electronic health records reveal gender and age biases in administration of known drug–drug interactions

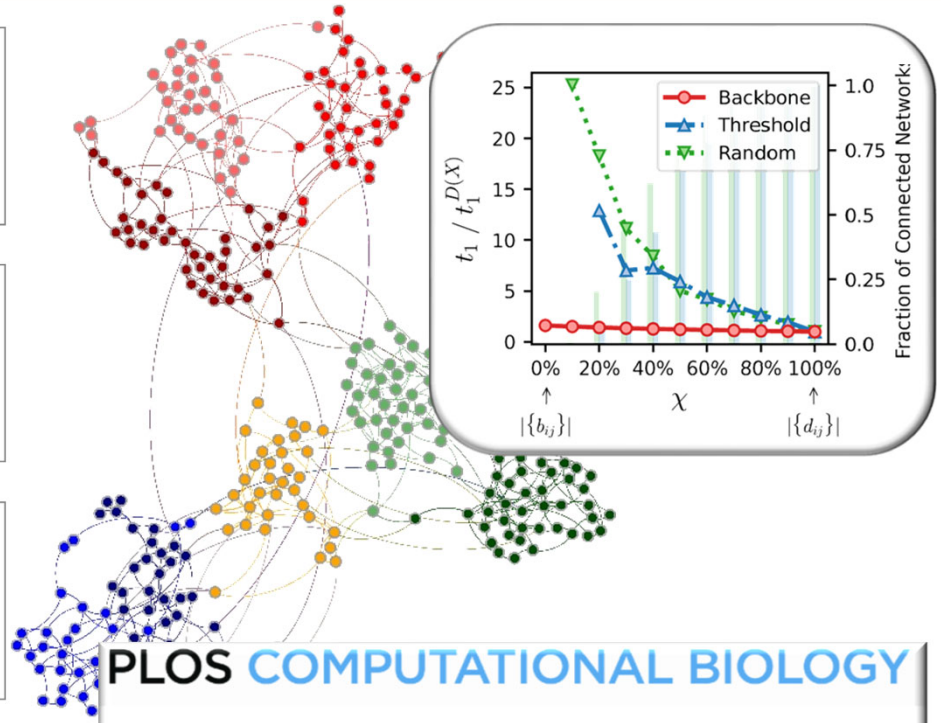
integrating and analyzing multilevel data sources with network science

to predict disease spread, information integration









PLOS COMPUTATIONAL BIOLOGY

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

Contact networks have small metric backbones that maintain community structure and are primary transmission subgraphs

Rion Brattig Correia, Alain Barrat, Luis M. Rocha

frontiers in NEUROINFORMATICS

ORIGINAL RESEARCH ARTICLE

Multi-scale integration and predictability in resting state brain activity

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Simas & Rocha [2015]. *Network Science*. doi:10.1017/nws.2015.11

Simas, Correia & Rocha [2021]. *J Complex Networks*. **9** (6), cnab021.


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LIVE IN LISBON
TikTok
@djetrash
FEB 21 - 10 PM - NO COVER
FRIDAY, AUGUST 19: 1AM (BASEMENT)

what about you?

- Background
- Interests
- Course expectations

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course materials

- Lecture notes
  - See course web page and blog
- Class Handouts
  - Web page and brightspace
- Class Book
  - Floreano, D. and C. Mattiussi [2008]. *Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies*. MIT Press.
- Recommended or alternative books
  - Flake, G. W. [1998]. *The Computational Beauty of Nature: Computer Explorations of Fractals, Complex Systems, and Adaptation*. MIT Press.
  - Forbes, N. [2004]. *Imitation of Life: How Biology is Inspiring Computing*. MIT Press.
  - Gleick, J. [2011]. *The Information: A History, a Theory, a Flood*. Random House.
  - De Jong, K. [2016] A. *Evolutionary Computation*: *A Unified Approach*. MIT Press.
  - Mitchell, M. [2019]. *Artificial intelligence : a guide for thinking humans*. Farrar, Straus and Giroux.
  - Mitchell, M. [2009]. *Complexity: A Guided Tour.* Oxford University Press.
  - Mitchell, M. [1999]. *An Introduction to Genetic Algorithms*. MIT Press.
  - Nunes de Castro, Leandro [2006]. *Fundamentals of Natural Computing: Basic Concepts, Algorithms, and Applications*. Chapman & Hall.
  - Nunes de Castro, Leandro and Fernando J. Von Zuben [2005*]. Recent Developments in Biologically Inspired Computing.* MIT Press.
  - Prusinkiewicz and Lindenmeyer [1996] *The algorithmic beauty of plants*.

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overview

- *Bio-inspired computing* is a field devoted to tackling complex problems using computational methods modeled after **design principles encountered in nature**.
  - Strongly grounded on the foundations of *complex systems* and *theoretical biology*.
  - The goal is a deep *understanding* of the **distributed architectures of natural complex systems**, and how those can be used to produce **informatics tools** with enhanced robustness, scalability, flexibility and which can interface more effectively with humans.
  - It is a **multi-disciplinary** field strongly based on biology, complexity, computer science, informatics, cognitive science, robotics, and cybernetics.
- Aims
  - Students will be introduced to fundamental topics in bio-inspired computing, and build up their proficiency in the application of various algorithms to real-world problems.
    - computational intelligence, modeling and simulation, machine learning, evolutionary systems, artificial life, and biology itself.

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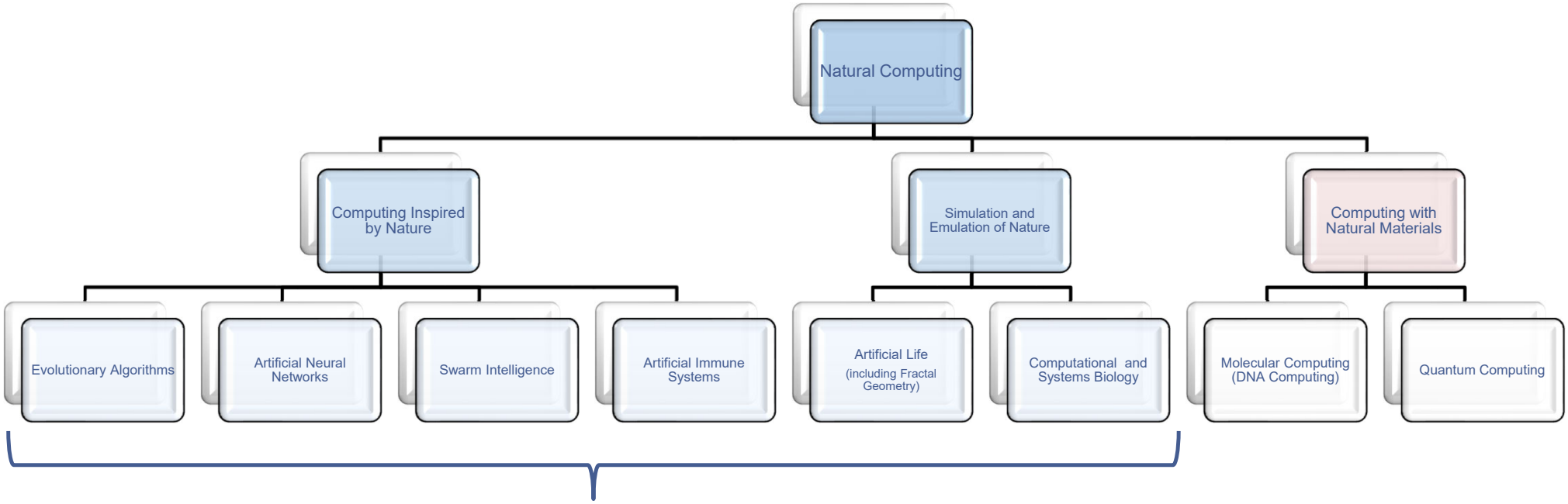
adapted from Nunes de Castro



Complex Systems Science Approach

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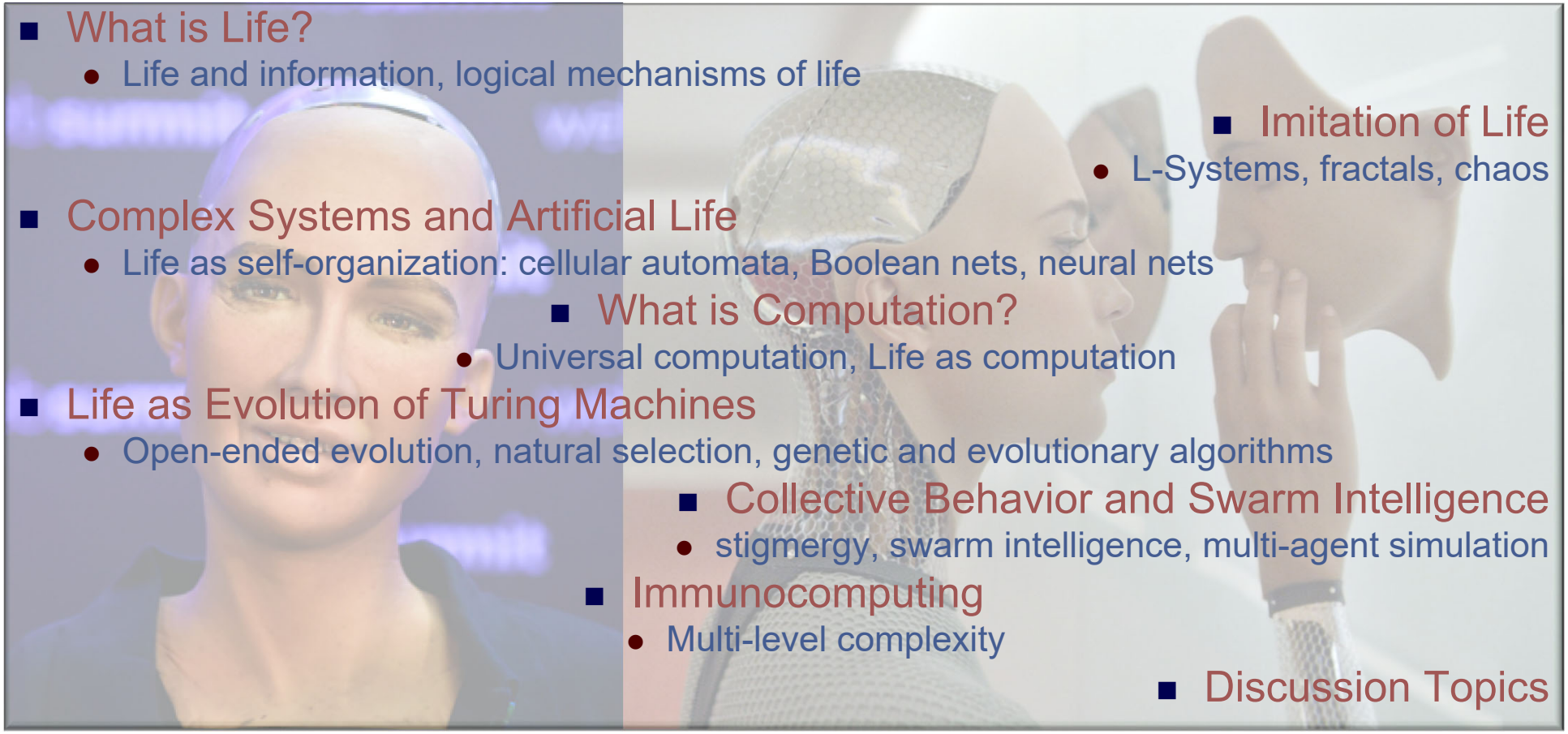
syllabus



- What is Life?
  - Life and information, logical mechanisms of life
- Imitation of Life
  - L-Systems, fractals, chaos
- Complex Systems and Artificial Life
  - Life as self-organization: cellular automata, Boolean nets, neural nets
- What is Computation?
  - Universal computation, Life as computation
- Life as Evolution of Turing Machines
  - Open-ended evolution, natural selection, genetic and evolutionary algorithms
- Collective Behavior and Swarm Intelligence
  - stigmergy, swarm intelligence, multi-agent simulation
- Immunocomputing
  - Multi-level complexity
- Discussion Topics

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evaluation

- Participation: 15%.
  - Based upon attendance and participation.
- Labs
  - ISE-483 Assignments: 35%
    - Students complete 5 (4 best) assignments on algorithms presented in class
  - SSIE-583 Lab Delivery: 25%
    - Groups develop, deliver, and assist grading two ISE-484 lab assignments
- SSIE-583 - Presentation and Discussion: 25%
  - Students will present and lead the discussion of an article related to the class materials. This includes presenting concepts necessary to understand the article.
- Project Paper: 50% (ISE-483), 35% (SSIE-583)
  - Students can choose to tackle a real problem using bio-inspired algorithms, or write a term paper (in Conference Style).
    - Students are expected to continuously consult with the instructor regarding the scope and depth of the project paper. Reusing and expanding labs is highly encouraged.
    - Project ideas available.

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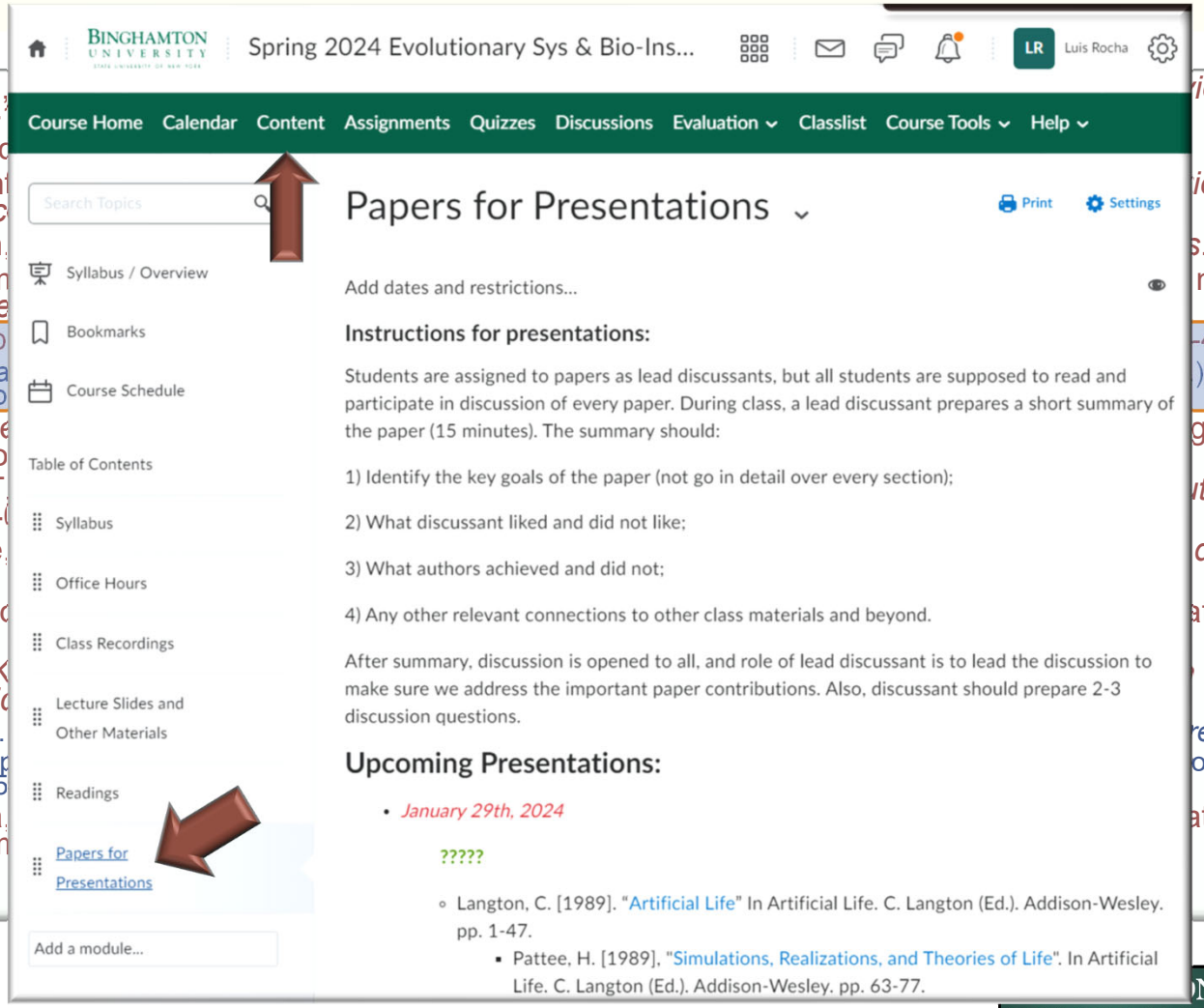
SSIE-583 - possible presentations

Some classics



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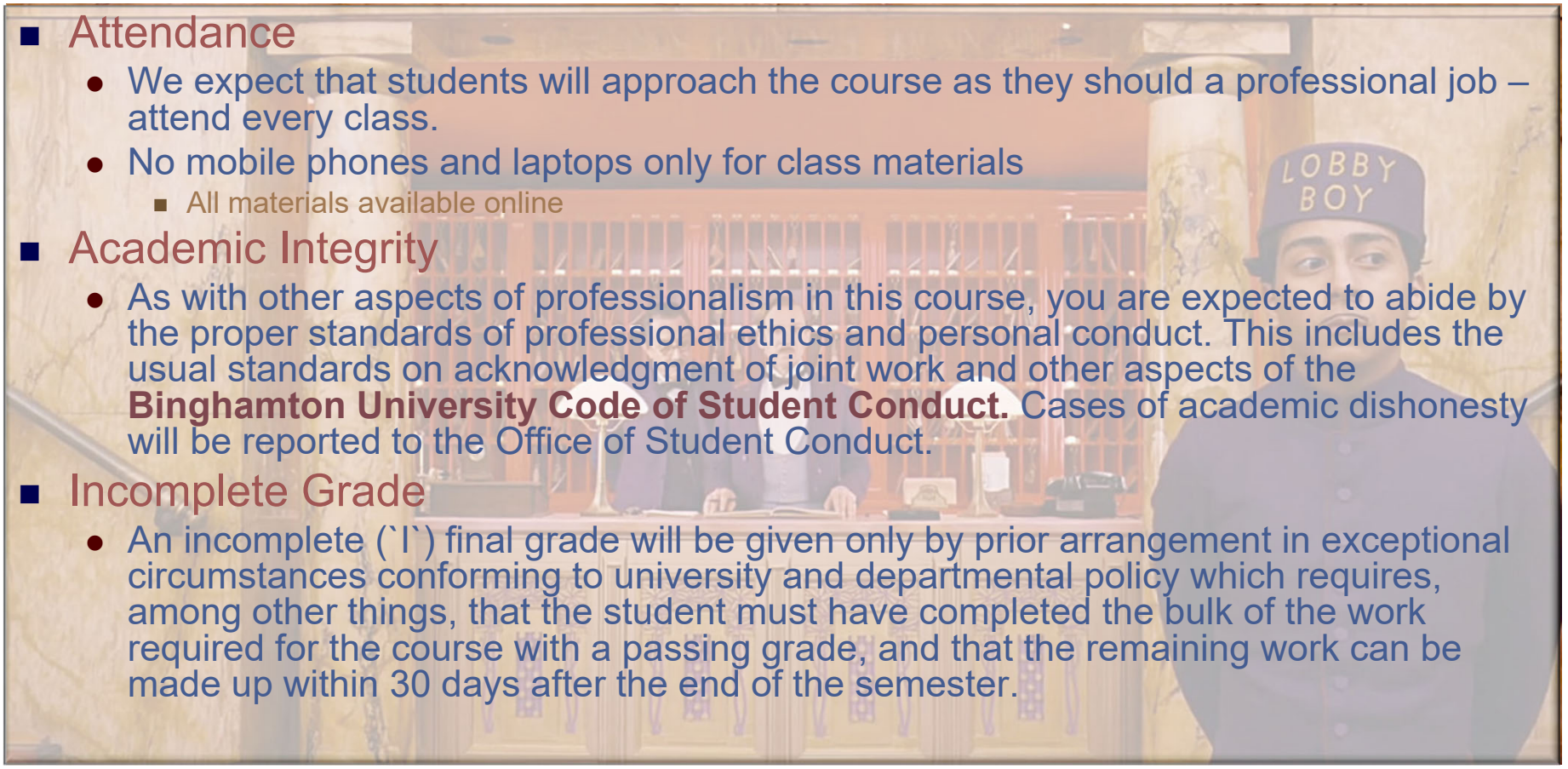
but collegiality above all



- Attendance
  - We expect that students will approach the course as they should a professional job – attend every class.
  - No mobile phones and laptops only for class materials
    - All materials available online
- Academic Integrity
  - As with other aspects of professionalism in this course, you are expected to abide by the proper standards of professional ethics and personal conduct. This includes the usual standards on acknowledgment of joint work and other aspects of the **Binghamton University Code of Student Conduct.** Cases of academic dishonesty will be reported to the Office of Student Conduct.
- Incomplete Grade
  - An incomplete (`I`) final grade will be given only by prior arrangement in exceptional circumstances conforming to university and departmental policy which requires, among other things, that the student must have completed the bulk of the work required for the course with a passing grade, and that the remaining work can be made up within 30 days after the end of the semester.

definition of grades

for course

A+ **A** **A-**	**98%** **94** **90**	*Excellent Work*. Student performance demonstrates thorough knowledge of the course materials and exceeds course expectations by completing all requirements in a superior manner.
B+ **B** **B-**	**85** **80** **75**	*Very Good Work*. Student performance demonstrates above-average comprehension of the course materials and exceeds course expectations on all tasks as defined in the course syllabus.
C+ **C** **C-**	**70** **65** **60**	*Good Work*. Student performance meets designated course expectations and demonstrates understanding of the course materials at an acceptable level.
D+ **D** **D-**	**55** **50** **45**	*Marginal Work*. Student performance demonstrates incomplete understanding of course materials.
F	**Less than 45**	*Fail*.

key events coming up

- Labs: 35% (ISE-483)
  - Complete 5 (best 4 graded) assignments based on algorithms presented in class
    - Lab 0 : January 29th
      - *Introduction to Python* (No Assignment)
        - Delivered by SSIE583 Group 2
    - Lab 1 : February 5th
      - *Measuring Information* (Assignment 1)
        - Delivered by SSIE583 Group 3
- SSIE – 583 -Presentation and Discussion: 25%
  - Present and lead the discussion of an article related to the class materials
    - Enginet students post/send video or join by Zoom
  - First presentation January 29th
    - Langton, C. [1989]. “Artificial Life” In *Artificial Life*. C. Langton (Ed.). Addison-Wesley. pp. 1-47.
      - Pattee, H. [1989], "Simulations, Realizations, and Theories of Life". In *Artificial Life*. C. Langton (Ed.). Addison-Wesley. pp. 63-77.
        - Presented by?
        - Discussion by all

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lecture 1

what is life?

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historically, not a relevant question

Animism by Georgeanne

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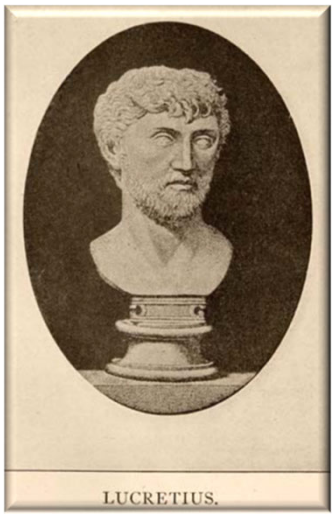
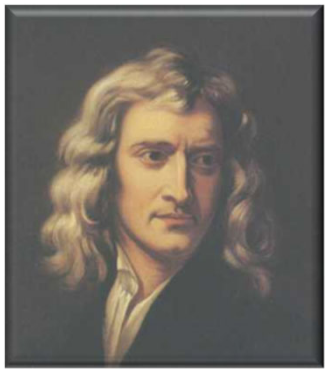
how?





- Lucretius (ca 66 B.C)
  - How can choice arise if all **atoms** follow inexorable mechanical courses?
    - Titus Lucretius Carus
    - Epicurean Roman poet
  - Free Will vs. determinism
    - Also Aquinas…
- Universal Mechanism
  - The universe is best understood as a completely mechanical system
    - A system composed entirely of matter in motion under a complete and regular system of ***laws of nature***.
  - Materialism, determinism
    - Laplace, Hobbes,….
- Newton
  - everything explained according to the operation of a single mechanical principle

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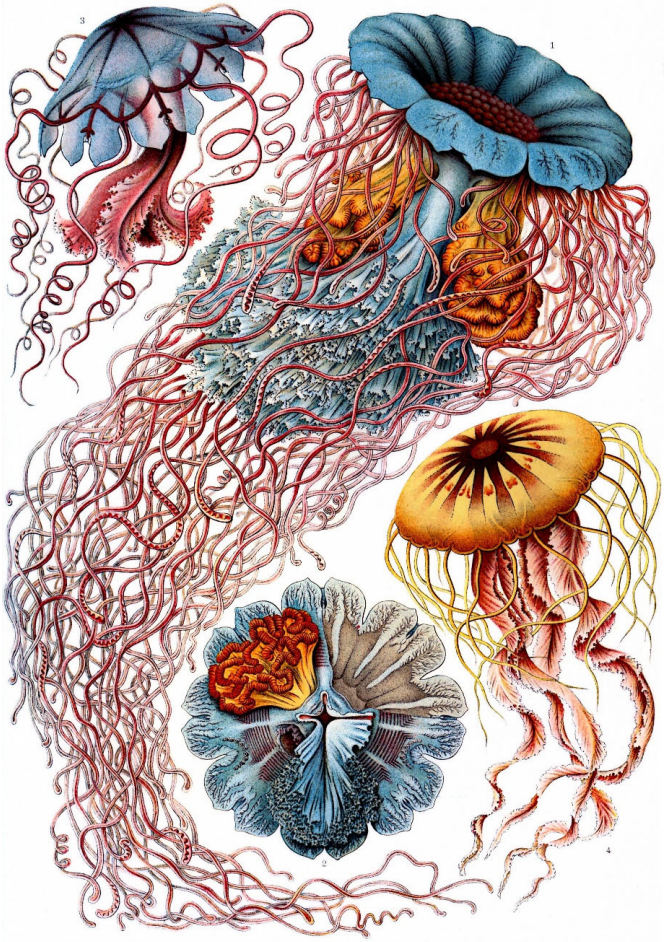
Webster's dictionary

- life adj.
  - the general ***condition that distinguishes organisms from inorganic objects and dead organisms***, being manifested by *growth* through *metabolism*, a means of *reproduction*, and internal *regulation in response* to the environment.
  - the *animate existence* or period of animate existence of an individual.
  - a corresponding state, existence, or principle of existence conceived of as belonging to the *soul*.
  - the period of existence, activity, or effectiveness of something inanimate, as a machine, lease, or play.
  - *animation*; liveliness; *spirit*: the force that makes or keeps something alive; the *vivifying or quickening principle*.



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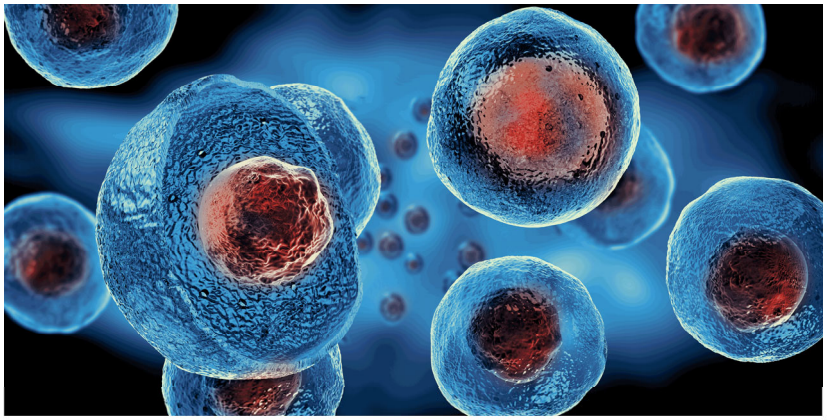
for life

- **Organization** distinct from inorganic matter
  - with an associated list of properties
  - matter controlled by genomic information
- **Animated behavior**
- Vitalism
  - life as a special, incommensurable, quality
  - Not a viable scientific explanation, because for science nothing is in principle incommensurable.
  - Pertains to metaphysics.
    - If the agent of design cannot be observed with physical means, then it is by definition beyond the scope of science as it cannot be tested.
  - See Dennett's and Polt's pieces



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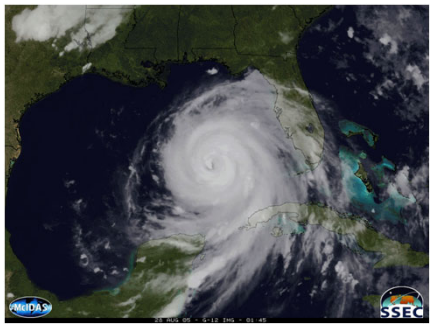
how to identify it?

- List of properties
  - Growth
  - Metabolism
  - Reproduction
  - Adaptability
  - Self-maintenance (autonomy)
  - Self-repair
  - Self-assembly
  - Reaction
  - Evolution
  - Choice
- Threshold of complexity
  - Closure (metabolic, functional)
    - Categorization and Control
    - Function (self-reference)
  - Open-ended evolution
  - (genomic) Information

Is life Fuzzy?

Is there a synthetic criteria? How general can it be?

self-assembling wires?



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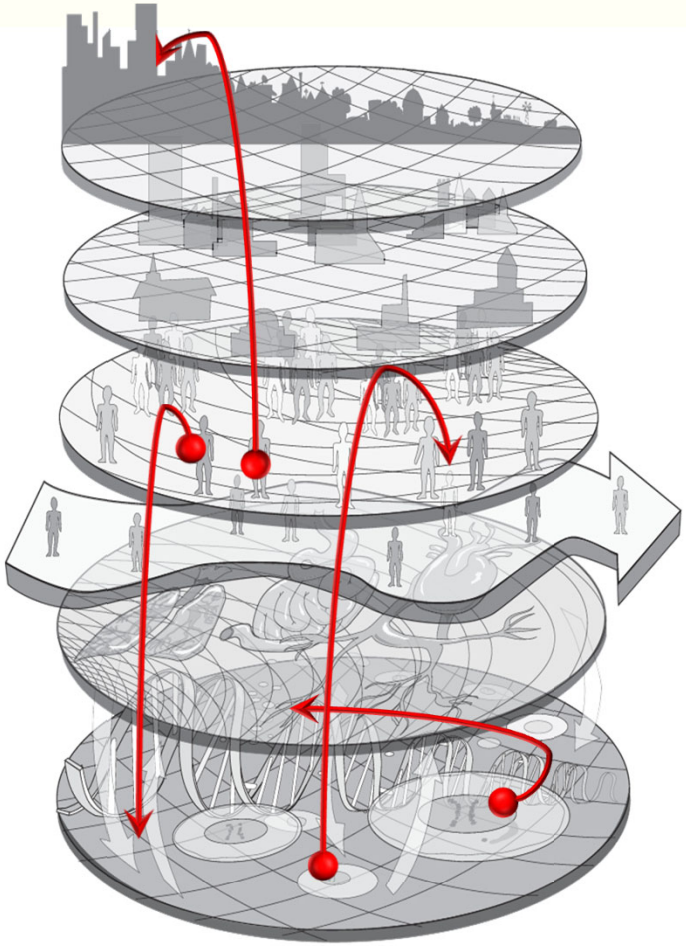
complexity threshold

- Science often sees life as the complicated physics of a collection of moving bodies
  - Reductionist search for answers in the nitty-gritty of biochemistry
    - Separable variables or near-decomposable modules (Simon)
  - When do we reach a threshold of complexity after which matter is said to be living?
    - Which variables, networks, components, relations must be included?
- Life as (emergent) organization
  - Systems Thinking
    - Ludwig von Bertallanfy (1980)
    - What is important are not the actual physical components but the relations amongst them
  - But what about evolution and history?
    - Conflict between (general) organization and specific components with their history
    - What organization explains evolution?



Pescosolido, B.A. 2006. Journal of Health and Social Behavior 47: 189-208.

"Seeking a connecting link, they had condescended to the preposterous assumption of structureless living matter, unorganized organisms, which darted together of themselves in the albumen solution, like crystals in their mother-liquor; yet organic differentiation still remained at once condition and expression of all life. **One could point to no form of life that did not owe its existence to procreation by parents**". Thomas Mann [1924].

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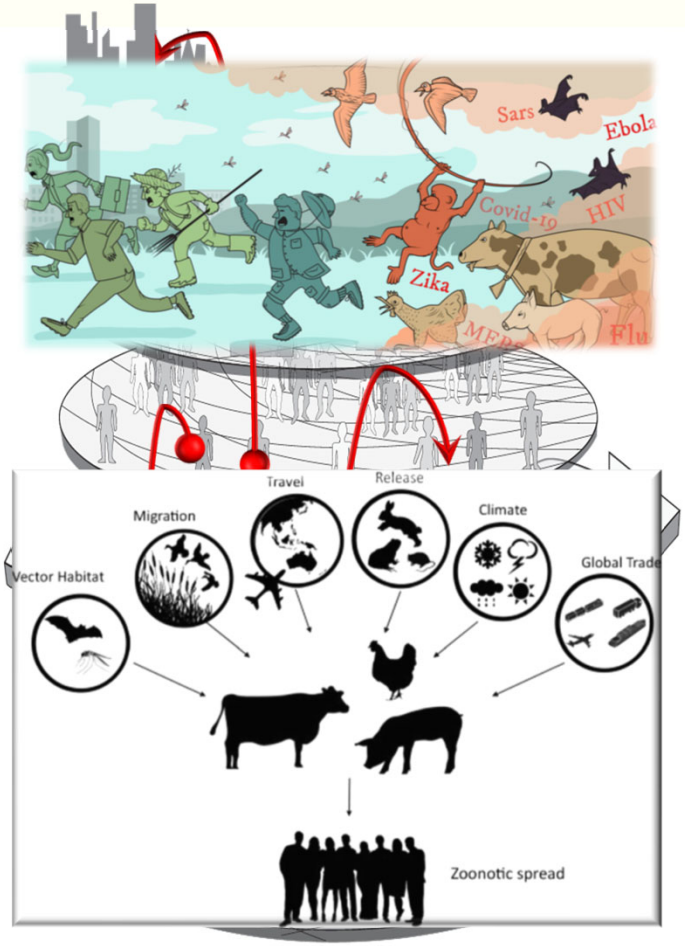

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