Binghamton University

EngiNet™

State University of New York

WARNING

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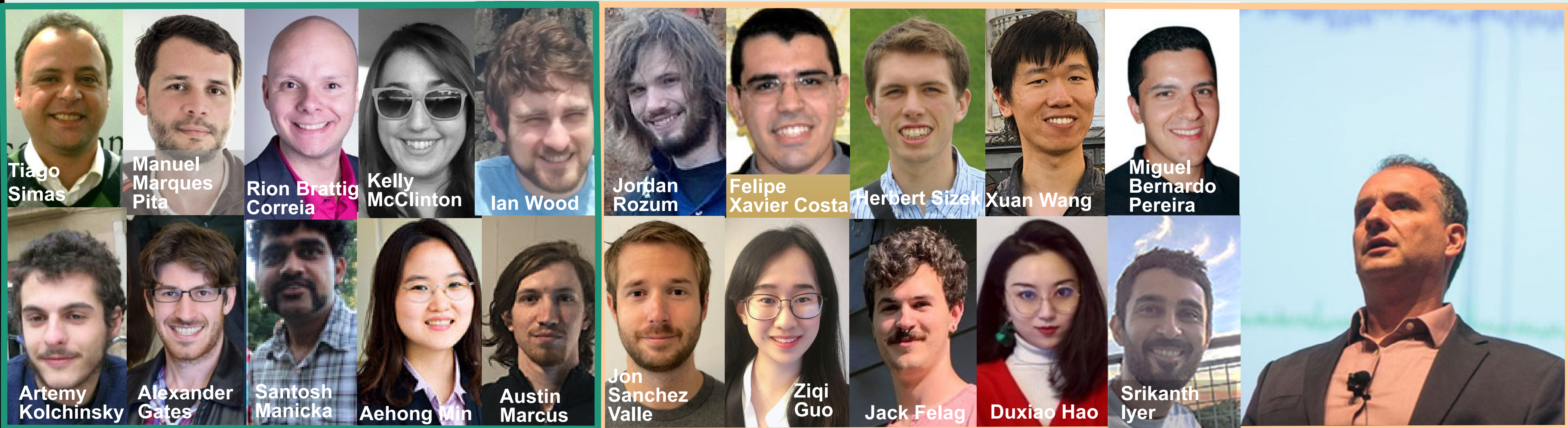
Fax: 1-800-258-6640 or 607-777-6254

Media Production Operator: **TBA**

Instructor: Prof. **Luis M. Rocha**
Email: rocha@binghamton.edu
Phone: 607-777-5934

TA: **TBA**

evolutionary systems and bio-inspired computing



what I do

luis m. rocha

FULBRIGHT

PERSISTENT

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

NSF

BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK

careerbuilder

IARPA BE THE FUTURE

FUNDAÇÃO LUSO-AMERICANA

CATÓLICA BIOMEDICAL RESEARCH CENTRE

cnrs

European Commission

horizon europe

NIH NLM

rocha@binghamton.edu
casci.binghamton.edu/academics/i-bic

Complex adaptive systems and computational intelligence (casci lab)

Resources
- web page
  - casci.binghamton.edu/academics/i-bic/
- online class
  - Link on Brightspace
- blog: life inspired
  - life-inspired.blogspot.com
- Brightspace
  - https://brightspace.binghamton.edu/d2l/home/412760

bit.ly/atBIC

SSIE-501/ISE-440 - Fall 2024

luis m. rocha

office hours:
TBA????

office hours:
thursdays 9:00- 11:30am, EB S04
binghamton.zoom.us/my/luismrocha

rocha@binghamton.edu
casci.binghamton.edu/academics/i-bic

CATÓLICA BIOMEDICAL RESEARCH CENTRE

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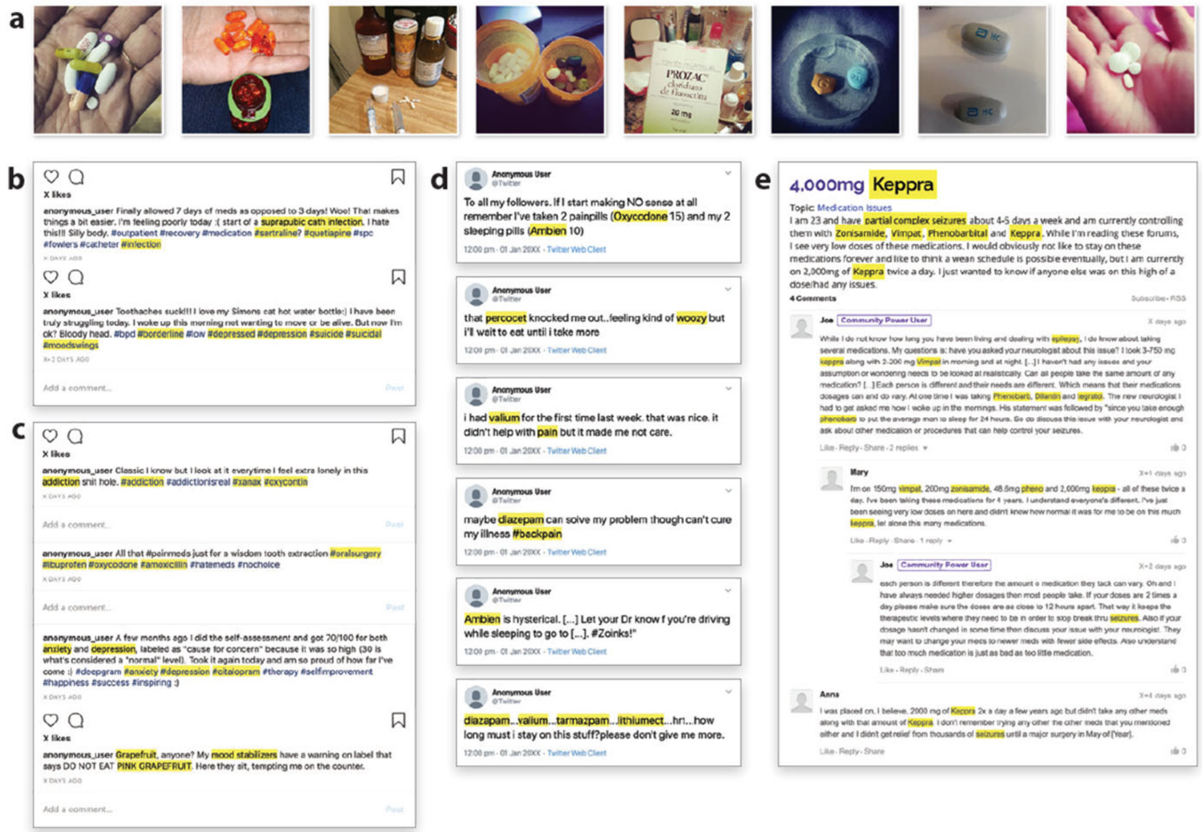
Lisbon


Luanda

social media data pipelines for biomedicine



Min et al [2023]. *CHI 2023*. **32.**
Wood, Correia, Miller, &Rocha [2022]. *Epilepsy & Behavior*. **128**: 108580.
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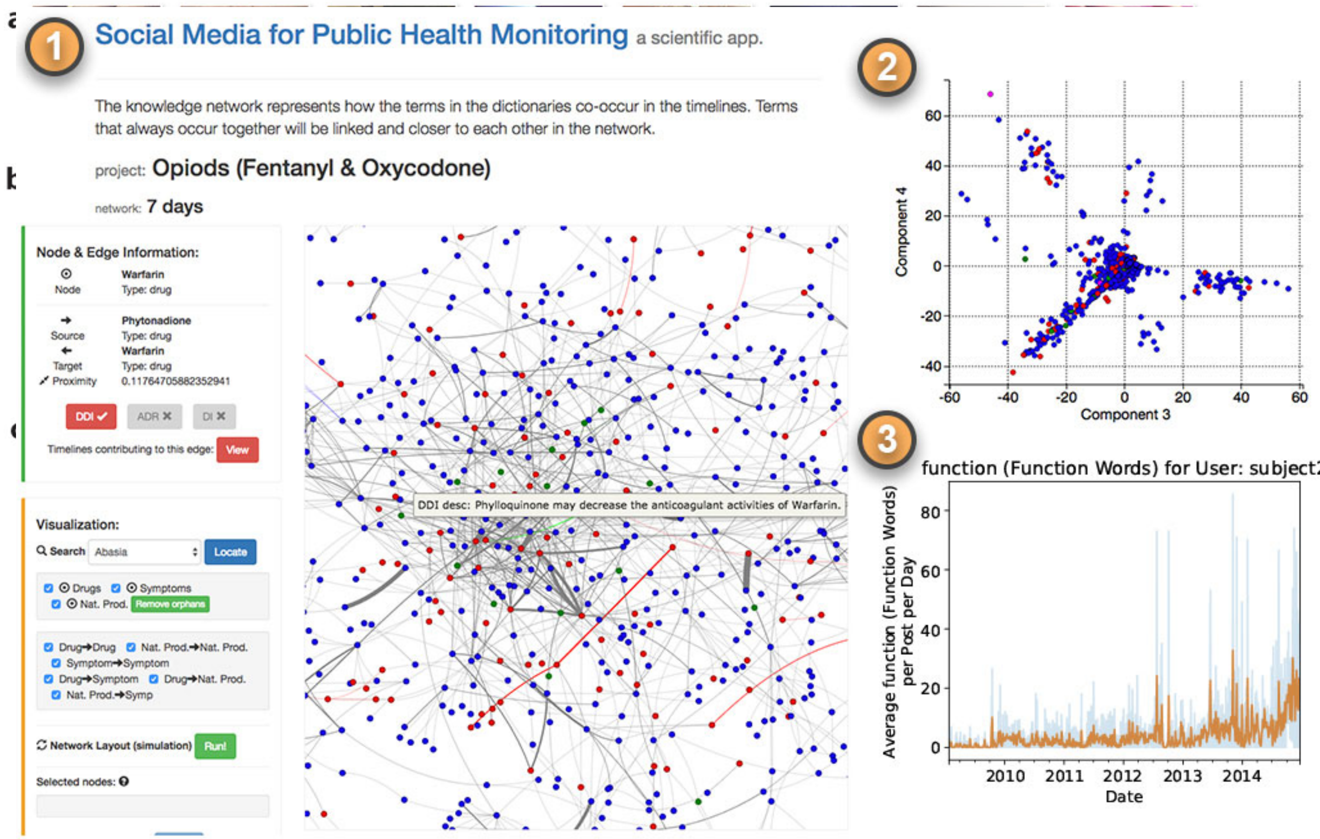
casci.binghamton.edu/academics/i-bic

Correia, Wood, Bollen, & Rocha [2020]. *Annual Review of Biomedical Data Science*, 3:1.
Wood, Varela, Bollen, Rocha & Sá [2017]. *Scientific Reports. 7: 17973* .

social media data pipelines for biomedicine



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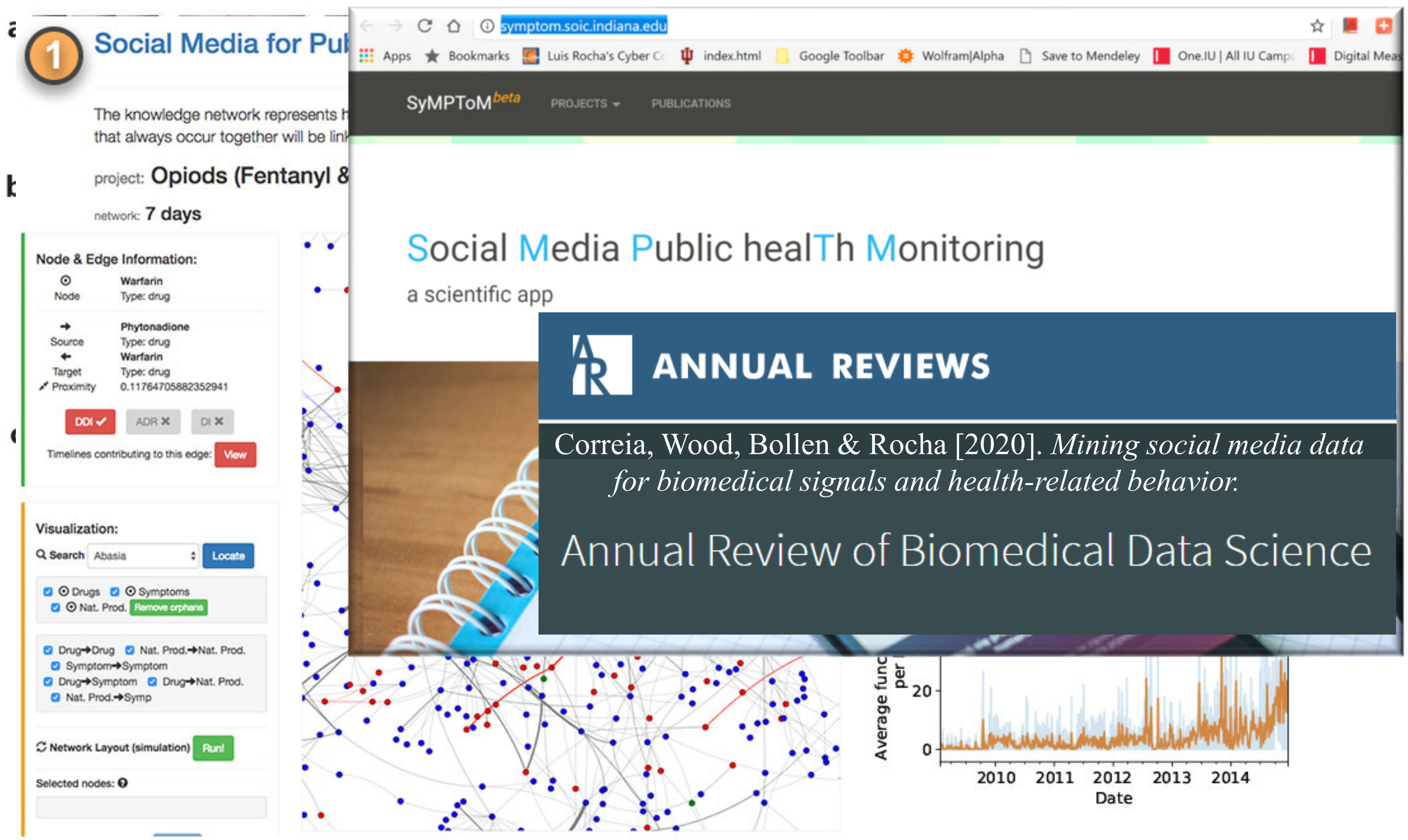

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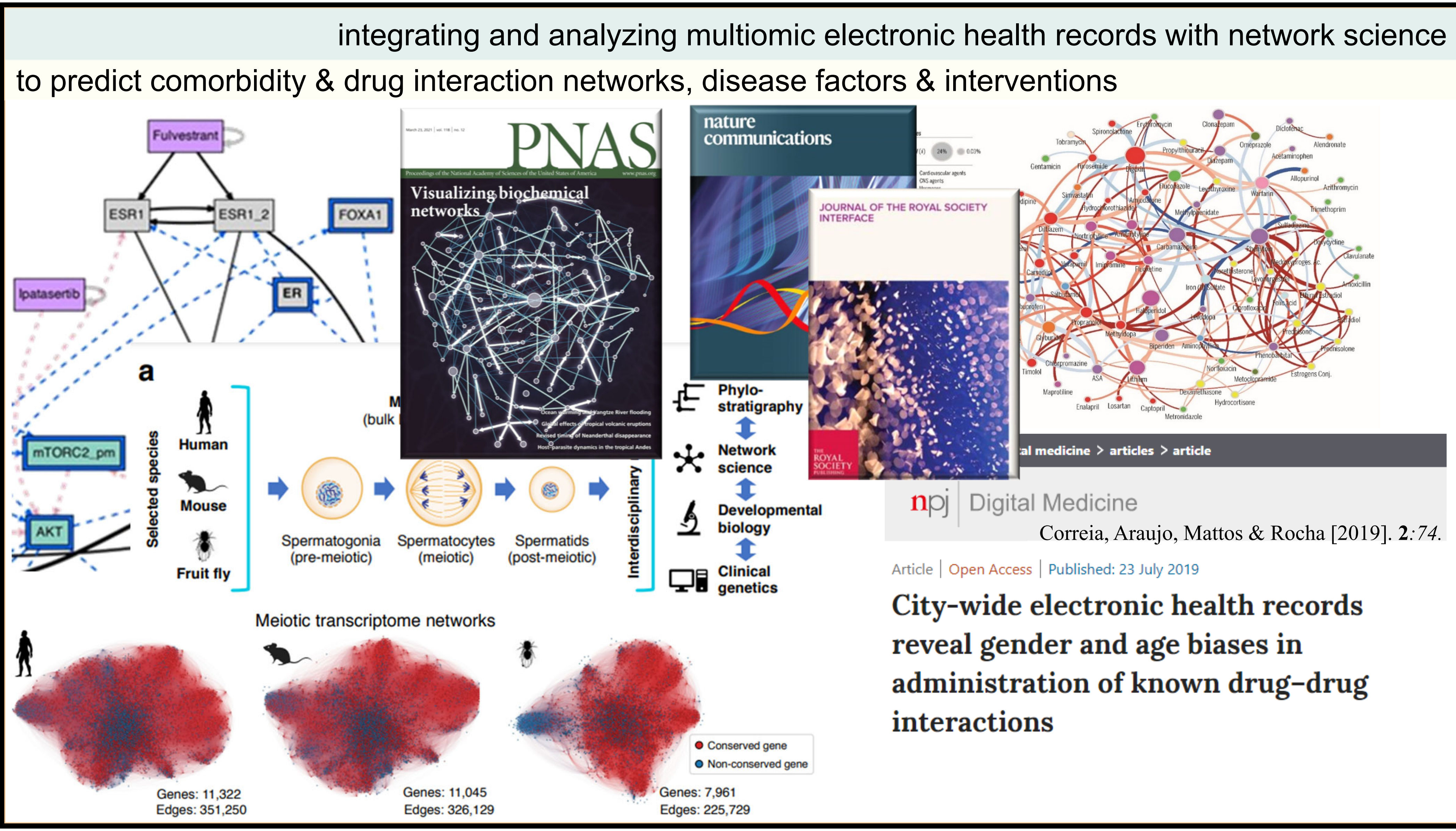
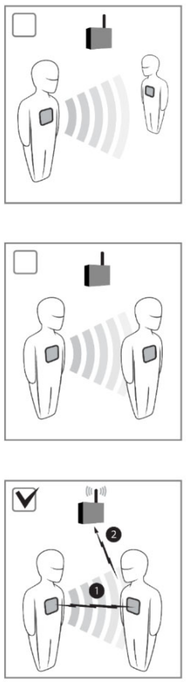
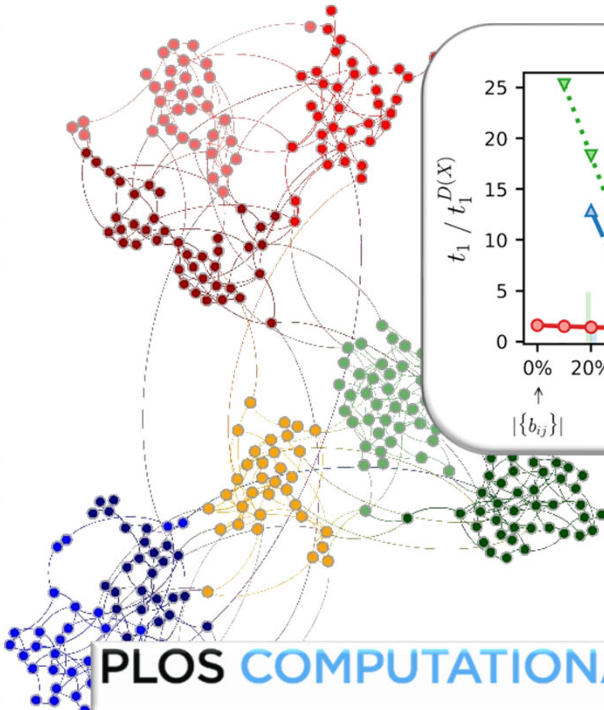
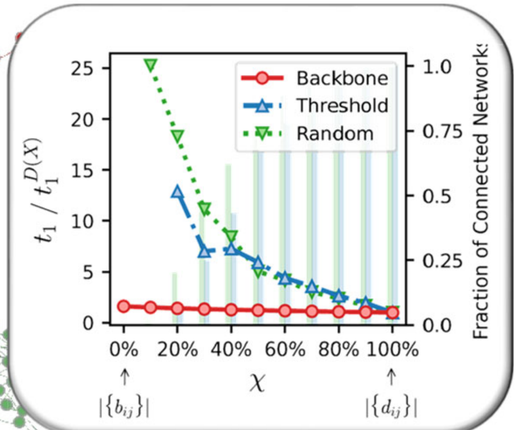

integrating and analyzing multiomic electronic health records with network science
to predict comorbidity & drug interaction networks, disease factors & interventions
Fulvestrant
ESR1
ESR1_2
FOXA1
Ipatasertib
ER
mTORC2_pm
AKT
PNAS
Visualizing biochemical networks
nature communications
JOURNAL OF THE ROYAL SOCIETY INTERFACE
a
Selected species
Human
Mouse
Fruit fly
Spermatogonia (pre-meiotic)
Spermatocytes (meiotic)
Spermatids (post-meiotic)
Interdisciplinary
Phylo-stratigraphy
Network science
Developmental biology
Clinical genetics
Meiotic transcriptome networks
Genes: 11,322
Edges: 351,250
Genes: 11,045
Edges: 326,129
Genes: 7,961
Edges: 225,729
Conserved gene
Non-conserved gene
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

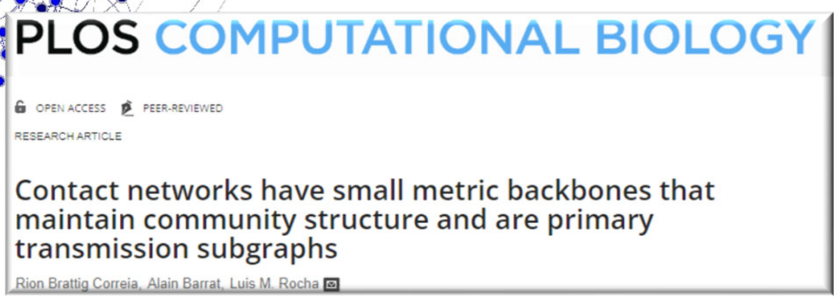
integrating and analyzing multilevel data sources with network science

to predict disease spread, information integration







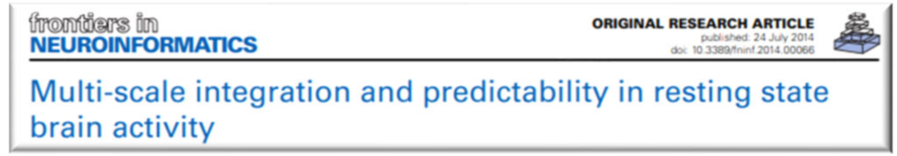

PLOS COMPUTATIONAL BIOLOGY

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

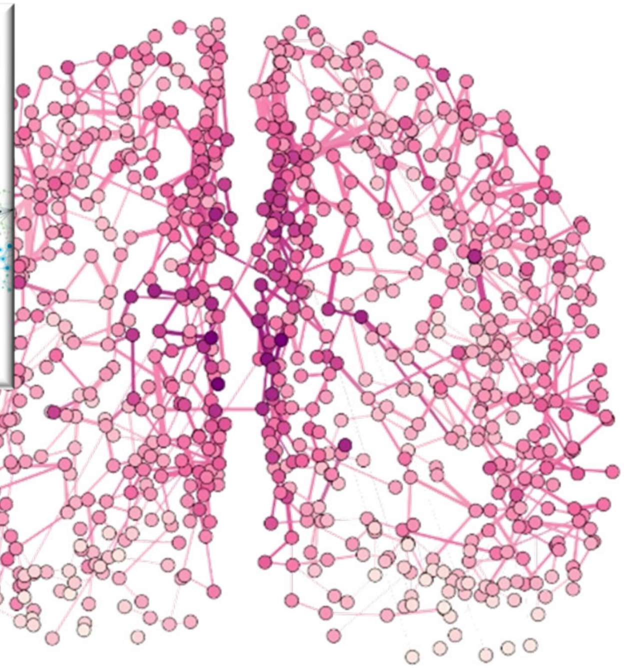
Contact networks have small metric backbones that maintain community structure and are primary transmission subgraphs

Rion Brattig Correia, Alain Barrat, Luis M. Rocha


frontiers in NEUROINFORMATICS

ORIGINAL RESEARCH ARTICLE
published: 24 July 2014
doi: 10.3389/fninf.2014.00066

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.


E-TRASH
LIVE IN LISBO
RIOT BOOTIQU
DJ ANGST
FEB 21 - 10 PM - NO COVER
FRIDAY, AUGUST 19: 1AM (BASEMENT)


E-TRASH
LIVE IN LISBO
TikTok
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TikTok
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@djetrash
NO COVER
FRIDAY, AUGUST 19: 1AM (BASEMENT)

- Background
- Interests
- Course expectations

General Issues

Topic	Threads	Posts	Last Post
Introductions For those online and anyone onsite who prefers this means. Please introduce yourself and why you are interested in this class	3	6	Luis Rocha 1 minute ago

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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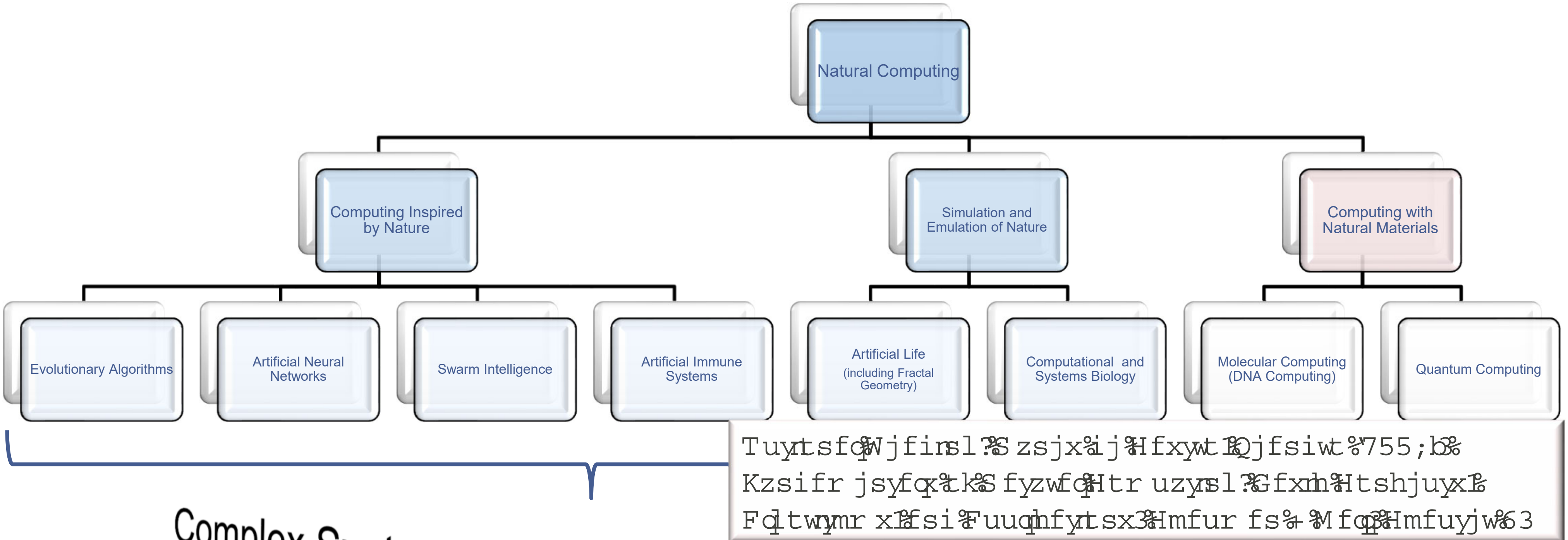
overview

- *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.

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%
    - Develop, deliver, and assist grading one ISE-484 lab assignment
- SSIE-583 - Presentation and Discussion: 25%
  - Present and lead the discussion of an article related to the class materials. This includes presenting concepts necessary to understand the article.
    - SSIE-687 students present 2-3 papers
- Project Paper: 50% (ISE-483), 35% (SSIE-583, SSIE-687)
  - 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.

Some classics

- Adami, C. [2006]. “Digital Genetics: Unraveling the Genetic Basis of Evolution”. *Nature Reviews Genetics.* **7**:109-118.
- Conrad, M. [1990]. "The geometry of evolution.“ *Biosystems* **24**: 61-81
- Crutchfield, J.P. and M. Mitchell [1995]."The evolution of emergent computation." *Proc. National Academy of Sciences*, USA, **92**: 10742-10746.
- Hinton, G.E. and S.J. Nowlan [1987]."How learning can guide evolution." *Complex Systems*. **1**, pp.495-502.
- Kauffman, S.A. [1969]. "Metabolic stability and epigenesis in randomly constructed genetic nets". *Journal of Theoretical Biology* **22**(3):437-467.
- 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.
- Lindgren, K. [1991]."Evolutionary Phenomena in Simple Dynamics." In: *Artificial Life II*. Langton et al (Eds). Addison-wesley, pp. 295-312.
- Ray, T. S. 1992. "Evolution, ecology and optimization of digital organisms". *Santa Fe Institute* working paper 92-08-042.
- Pattee, Howard H. [1969] "How does a molecule become a message?." *Communication in development* **3**: 1-16.
- Schmidt, M. and H. Lipson [2009]. “Distilling Free-Form Natural Laws from Experimental Data. *Science*, **324**: 81-85.
- Sims,K. [1994]. “Evolving Virtual Creatures”. *Proceedings of the 21st annual conference on Computer graphics and interactive techniques*, pp. 15 – 22.
  - H. Lipson and J. B. Pollack (2000), "Automatic design and Manufacture of Robotic Lifeforms", *Nature* **406**: 974-978.
  - Lipson H. (2005) "Evolutionary Design and Evolutionary Robotics", *Biomimetics*, CRC Press (Bar Cohen, Ed.) pp. 129-155
- Varela, Francisco J.; Maturana, Humberto R.; & Uribe, R. [1974]. “Autopoiesis: the organization of living systems, its characterization and a model”. *Biosystems.* **5** 187–196.

Some classics

Course Home Calendar Content Assignments Quizzes Discussions Evaluation Classlist Course Tools Help

Search Topics

Syllabus / Overview

Bookmarks

Course Schedule

Table of Contents 2

For EngiNet Students Only 2

Syllabus

Office Hours

Class Recordings

Lecture Slides and Other M...

Readings

Papers for Presentations

Papers for Presentations

Print Settings

Add dates and restrictions...

Instructions for presentations:

Students are assigned to papers as lead discussants, but all students are supposed to read and participate in discussion of every paper. During class, a lead discussant prepares a short summary of the paper (15 minutes). The summary should:

1) Identify the key goals of the paper (not go in detail over every section);

2) What discussant liked and did not like;

3) What authors achieved and did not;

4) Any other relevant connections to other class materials and beyond.

After summary, discussion is opened to all, and role of lead discussant is to lead the discussion to make sure we address the important paper contributions. Also, discussant should prepare 2-3 discussion questions.

Upcoming Presentations:

- *February 3rd, 2025*

Presenter 1

- 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.

Evolution". *Nature Reviews Genetics.*

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mputation." *Proc. National Academy of*

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ficial Life. C. Langton (Ed.). Addison-Wesley.

n: *Artificial Life II*. Langton et al (Eds).

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from Experimental Data. *Science*, **324**:

annual conference on Computer

Robotic Lifeforms", *Nature* **406**: 974-978.

netics, CRC Press (Bar Cohen, Ed.) pp. 129-

topoiesis: the organization of living

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*.

but collegiality above all

- Attendance
  - We expect that students will approach the course as they should a professional job – attend every class. Applies to ENGINET students.
  - 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.

key events coming up

- Labs: 35% (ISE-483)
  - Complete 5 (best 4 graded) assignments based on algorithms presented in class
    - Lab 0 : February 3rd
      - *Introduction to Python* (No Assignment)
        - Delivered by TBA
    - Lab 1 : February 10th
      - *Measuring Information* (Assignment 1)
        - Delivered by Shayan Esfarayeni
- 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 February 3rd
    - 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

lecture 1

What is life?

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historically, not a relevant question

Animism by Georgeanne

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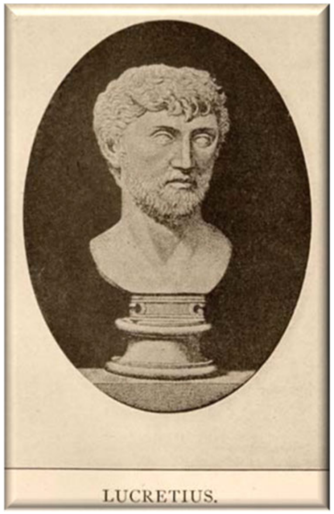
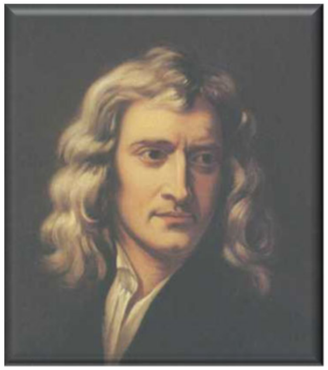
how?





- 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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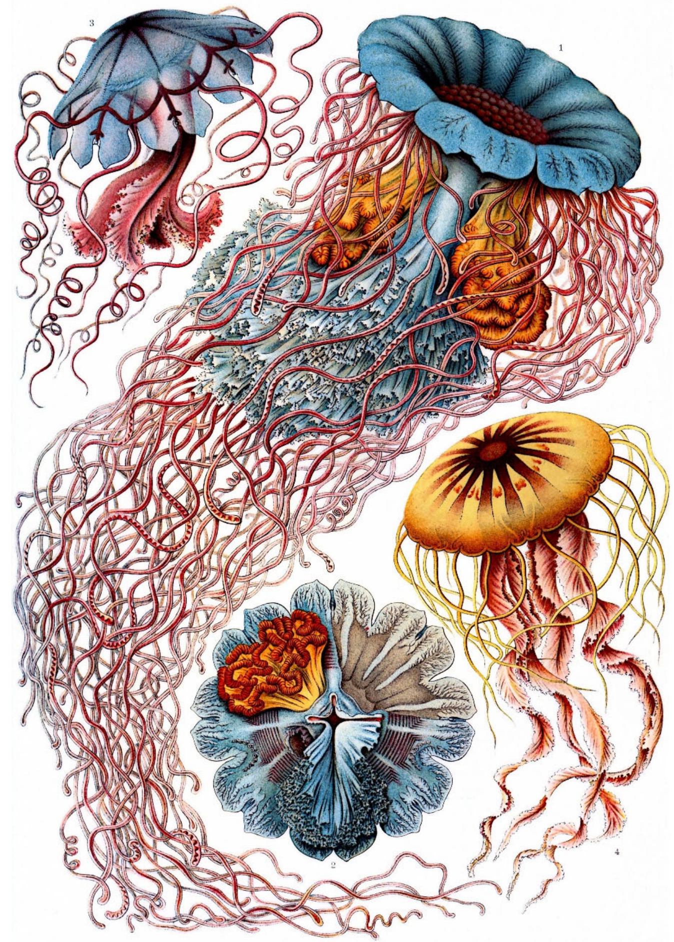
Webster's dictionary

- 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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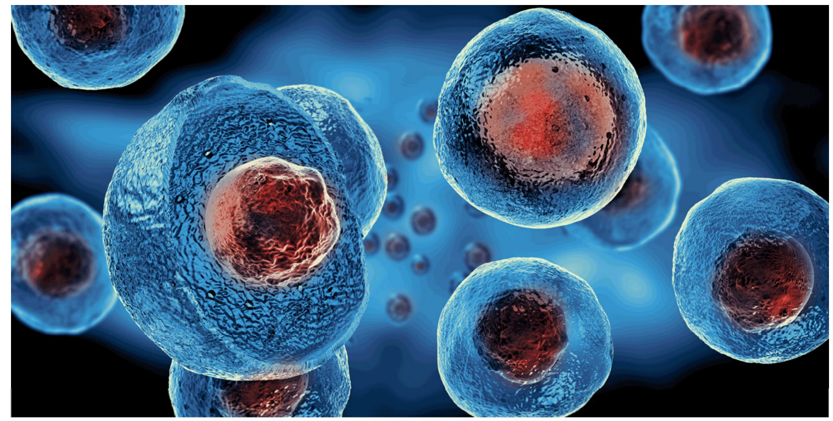
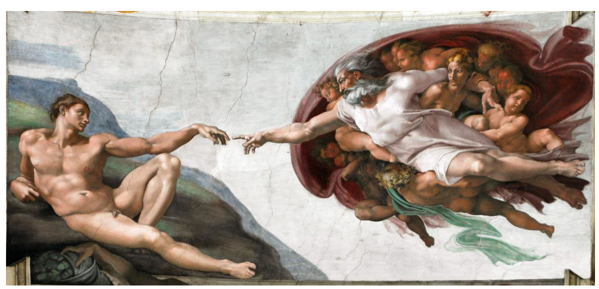
3 types of definitions

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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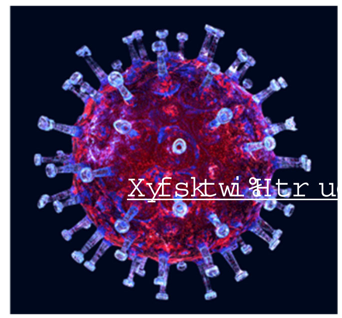
how to identify it?

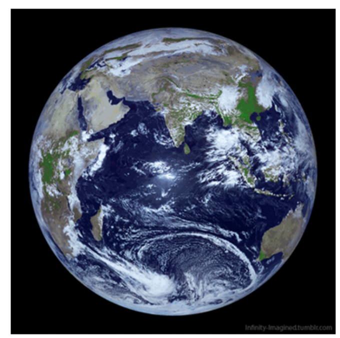
- List of properties
  - Growth
  - Metabolism
  - Reproduction
  - Adaptability
  - Self-maintenance (autonomy)
  - Self-repair
  - Self-assembly
  - Reaction
  - Evolution
  - Choice
- Threshold of complexity
  - Closure (metabolic, functional)
    - Categorization and Control
    - Function (self-reference)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

Is life Fuzzy?

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



viruses
candle flames
the Earth
hurricanes
robots
self-assembling wires?



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how to identify it?

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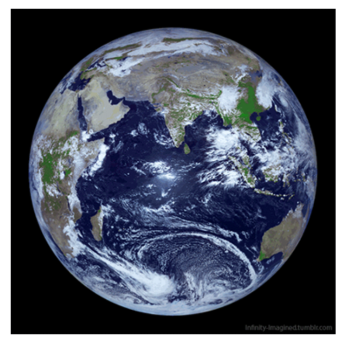
  - Self-repair
  - Self-assembly
  - Reaction
  - Evolution
  - Choice
- Threshold of complexity
  - Closure (metabolic, functional)
    - Categorization and Control
    - Function (self-reference)
  - Open-ended evolution
  - (genomic) Information

Is life Fuzzy?

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

self-assembling wires?



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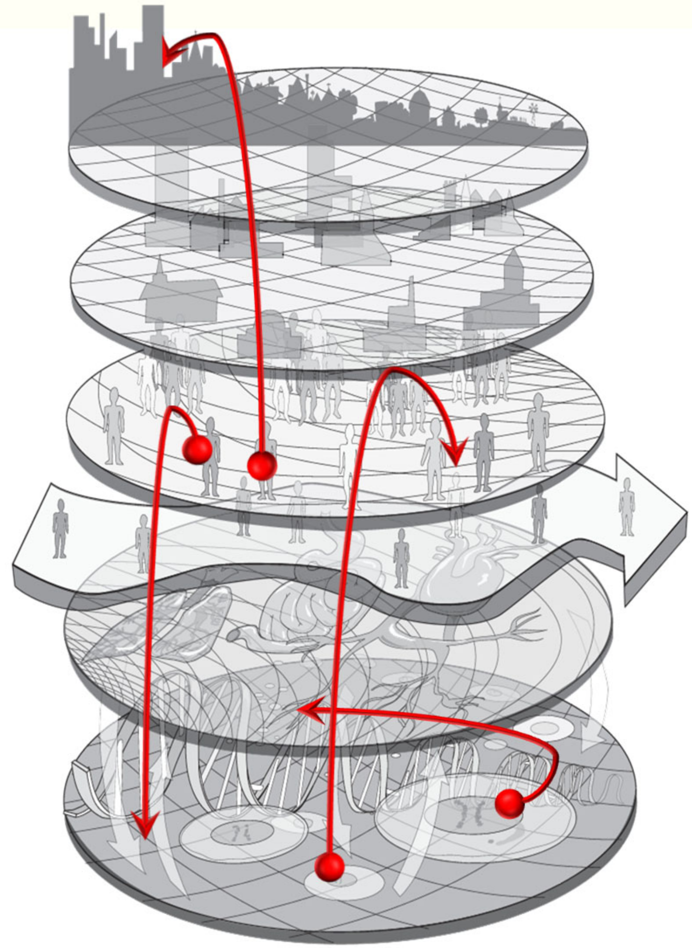
complexity threshold

- 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?

"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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