Overview of Complex Networks

Last updated: 2018/03/23, 12:08:15

Complex Networks | @networksvox
CSYS/MATH 303, Spring, 2018

Prof. Peter Dodds | @peterdodds

Dept. of Mathematics & Statistics | Vermont Complex Systems Center
Vermont Advanced Computing Core | University of Vermont



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Outline


THE GOLDEN AGE OF REDUCTIONISM
THE MANIFESTO
THE WELL OF SCALES
THE LAWS OF DECAYING POWER
THE UNEXPECTED TRANSFIGURATION
MINISTRY OF RANDOM WALKS
THE RICH GET RICHER
THE DREAM OF EFFICIENT LANGUAGE
THE LAW OF DIGITS FIRST
THE SURPRISE OF BEING ROBUST YET FRAGILE


THE MISREADING OF THE BOOK OF SAND
THE MANY TAILS OF MANY TAILS
THE MEASURING
THE DATA POOR
THE POURING DATA
THE CHARMS OF THE MANY WRONG PATHS
THE KNOWLEDGE OF DEAD MONKS
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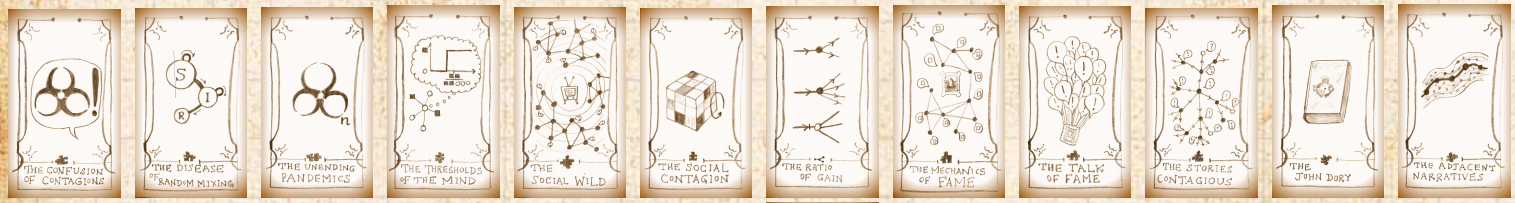
THE EMERGENCE OF STRUCTURE
THE EMERGENCE OF DESTRUCTION
THE EMERGENCE OF THINKING
It was the best of times,
THE EMERGENCE OF STORIES


THE MECHANICS STATISTICAL
THE THRESHOLDS OF PERCOLATION
THE NETWORKS COMPLEX
THE ELEMENTS OF WEBS
THE BIRDS OF A FEATHER
THE BIRDS OF NOT A FEATHER
THE ARK OF THE RANDOM NETWORK
THE STRANGENESS OF FRIENDS
THE SMALLNESS OF WORLDS
THE THEORY OF SIX DEGREES
THE NETWORKS FREE OF SCALE
CLASSIFIED PHOENIX
THE CONTAGION


THE CONFUSION OF CONTAGIONS
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THE STORYTELLERS
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THE SUPPLY TO THE MOST
THE DARK ART OF GENERATING FUNCTIONS
THE RANDOM SUM OF RANDOMNESS
THE TWO-SIDED WORLDS


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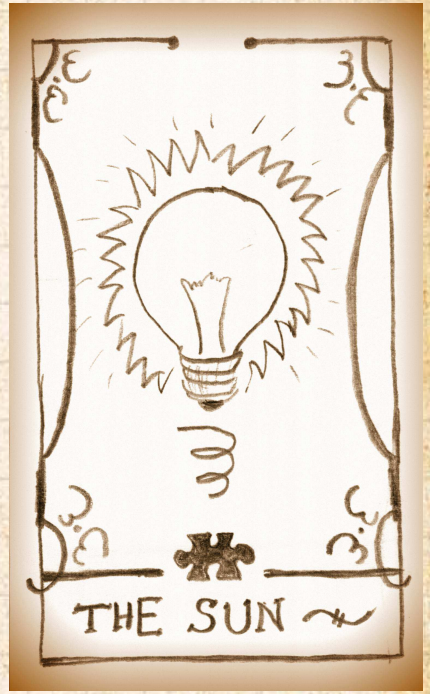
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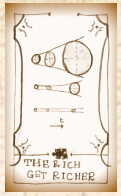
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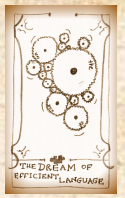
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THE
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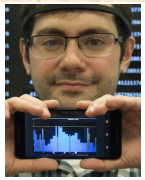
THE
JOHN DORY


Peter Dodds


Tyler Gray

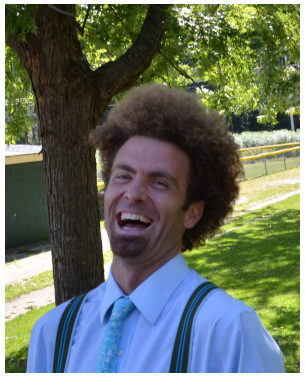

Aaron Schwartz


Eric Clark


Ben Emery


David Dewhurst


Colin Van Oort

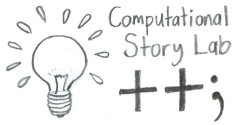

Chris Danforth


Abby Ross
Northfield Mount Hermon School


Chris Fusting
Data Science Consultant


Ryan Gallagher
Northeastern PhD student


John Ring



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Nick Allgaier
Psychiatry Postdoc, UVM


Dilan Kiley
Chobanian Group


Tom McAndrew
Cardiovascular Research Foundation


Emily Cody
Data Scientist
Adobe


Morgan Frank
MIT Media Lab
PhD Student


Cathy Bliss
UVM Lecturer


Mark Ibrahim
Data Scientist
Insight


Ross Lieb-Lappen
Dartmouth PhD
Cold Regions Research & Engineering Laboratory


Eitan Pechenick

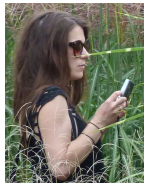

Andy Reagan
Data Scientist
MassMutual


Lewis Mitchell
Adelaide Faculty


Jake Williams
Drexel Faculty


Isabel Kloumann
Cornell PhD
Facebook
Data Scientist


Fletcher
Hazlehurst


Sharon Alajajian
Research Scientist
Univ of Pennsylvania


Kameron Harris
Washington
PhD Student


Paul Lessard
Colorado
PhD Student


Suma Desu
Apple
Data Scientist


Mike Foley
Northeastern
PhD student


Darcy Glenn
Climate Science
UC London, MS student

Funding: NSF, NASA, MITRE.

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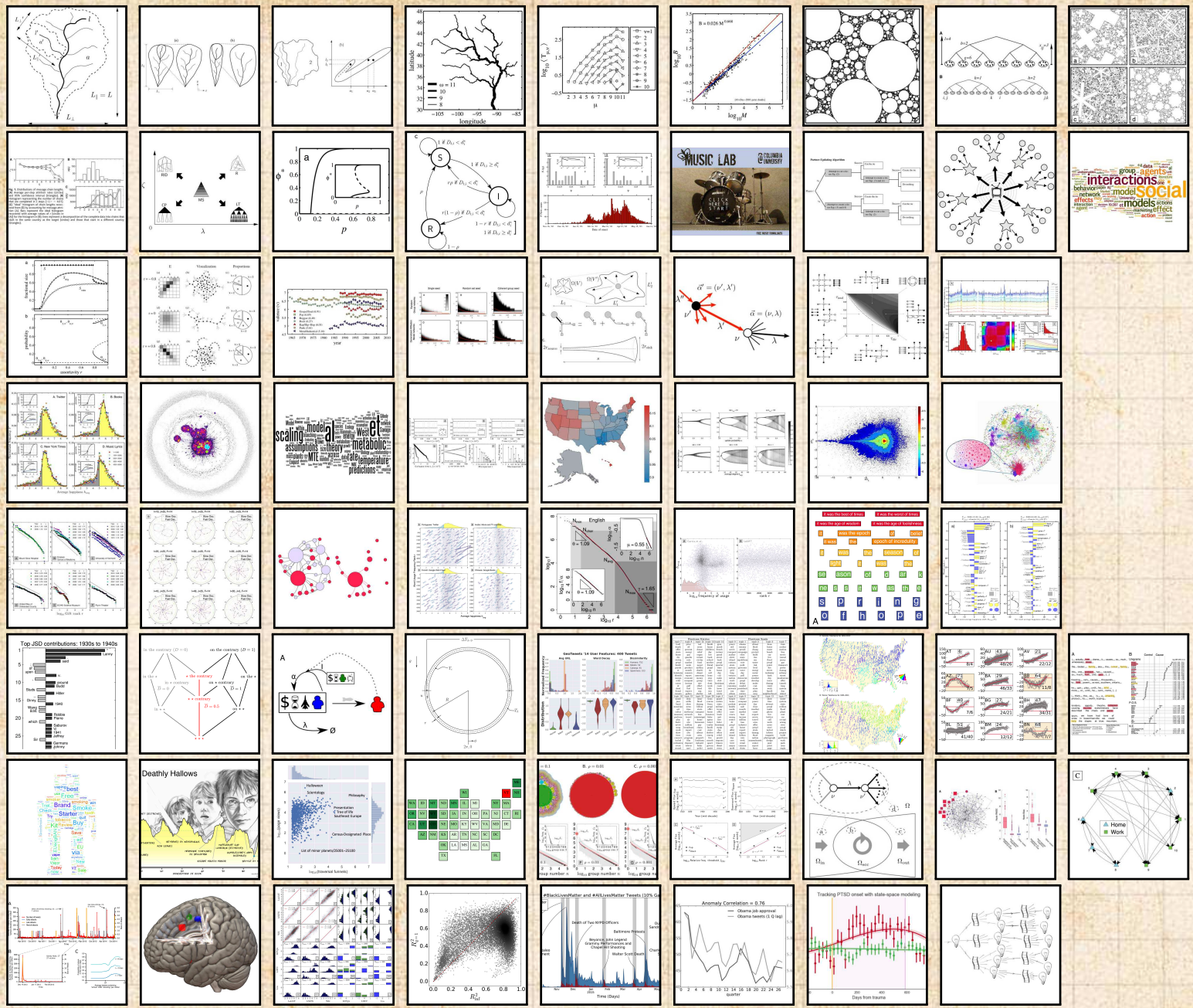

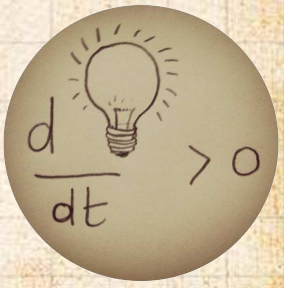

The University of Vermont

Outline

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Basics:

- Instructor: Prof. Peter Dodds
- Lecture room and meeting times:
  102 Perkins, Tuesday and Thursday, 8:30 am to 9:45 pm
- Office: Farrell Hall, second floor, Trinity Campus
- email: pdodds+coconuts@uvm.edu
- Course Website:
  http://www.uvm.edu/pdodds/teaching/courses/2018-01UVM-303
- Course Twitter handle: @networksvox
- Course hashtag: #SpringCOcoNuTS2018

Potential paper products:

- The Syllabus and a Poster.

Office hours:

- 10:05 am to 12:00 pm, Tuesday and Thursday, Farrell Hall, second floor, Trinity Campus

Graduate Certificate:

- Principles of Complex Systems is one of two core requirements for UVM's five course Certificate of Graduate Study in Complex Systems.
- Other required course: Prof. Maggie Eppstein's "Modelling Complex Systems" (CSYS/CS 302).
- coCoNuTS: The Sequel to PoCS: "Complex Networks" (CSYS/MATH 303).

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Details regarding these artisanal slides:

- Three versions (all in pdf):
  1. Presentation,
  2. Flat Presentation,
  3. Handout (3x2 slides per page).
- Presentation versions are hyperly navigable: ↶🔍↷≡ back + search + forward.
- Web links look like this and are eminently clickable.
- References in slides link to full citation at end.
- Citations contain links to pdfs for papers (if available).
- Some books will be linked to on amazon.
- Brought to you by a frightening melange of XeLaTeX, Beamer, perl, PerlTeX, fevered command-line madness, and an almost fanatical devotion to the indomitable emacs.

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More super exciting details:

- We use Open Sans and make math look good:

```
\setmainfont[Ligatures=TeX]{Open Sans}
\setsansfont[Ligatures=TeX]{Open Sans}
\usefonttheme[onlymath]{serif}
```

- Working towards putting the course on Github.
- And writing a book. A few books.

Yet more super exciting details:

- This is Season 8 of Complex Networks.
- Lectures will be called Episodes.
- All lectures are bottle episodes.
- Other tropes will be involved.

- Last coCoNuTs Episodes are here.

Wonderful foundational support for PoCS and CoNKS has come from the NSF:

- “CAREER: Explorations of Complex Social and Psychological Phenomena through Multiscale Online Sociological Experiments, Empirical Studies, and Theoretical Models.” 2009–2015.
- SES Division of Social and Economic Sciences SBE Directorate for Social, Behavioral & Economic Sciences
- Abstract is here.

- Last season’s Episodes are here.

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Team coCoNuTs

We'll be carrying on with the PoCS Slack:

- Place for discussions about all things PoCS/coCoNuTs including assignments and projects.
- Once invited, please sign up here: http://teampocs.slack.com
- Very good: Install Slack app on laptops, tablets, phone.
- Everyone will behave wonderfully.

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Grading breakdown:

- Projects/talks (36%)—Students will work on semester-long projects. Students will develop a proposal in the first few weeks of the course which will be discussed with the instructor for approval.

  Details: 12% for the first talk, 12% for the final talk, and 12% for the written project.

- Assignments (60%)—All assignments will be of equal weight and there will be 10 ± 1 of them.

- General attendance/Class participation (4%)

How grading works:

Questions are worth 3 points according to the following scale:

- 3 = correct or very nearly so.
- 2 = acceptable but needs some revisions.
- 1 = needs major revisions.
- 0 = way off.

Important things:

1. Classes run from Tuesday, January 16 to Thursday, May 4.
2. Add/Drop, Audit, Pass/No Pass deadline—Monday, January 29.
3. Last day to withdraw—Monday, April 2 (Never!).
4. Reading and Exam period—Monday, May 7 to Friday, May 11.

Do check the course Twitter account, @networksvox, for updates regarding the course (part of the course site).

Academic assistance: Anyone who requires assistance in any way (as per the ACCESS program or due to athletic endeavors), please see or contact me as soon as possible.

Schedule in detail:

Week number (dates)	Tuesday	Thursday
1 (1/16 and 1/18)	overview, branching networks I	branching networks I and II
2 (1/23 and 1/25)	branching networks II	optimal supply networks I and II
3 (1/30 and 2/1)	optimal supply networks II	optimal supply networks II
4 (2/6 and 2/8)	optimal supply networks II	optimal supply networks III
5 (2/13 and 2/15)	optimal supply networks III, random networks	random networks
6 (2/20 and 2/22)	generating functions	random bipartite networks
7 (2/27 and 3/1)	Town meeting day	project presentations†
8 (3/6 and 3/8)	Spring Recess	Spring Recess
9 (3/13 and 3/15)	random networks	bipartite networks
10 (3/20 and 3/22)	contagion	contagion
11 (3/27 and 3/29)	contagion	chaotic contagion
12 (4/3 and 4/5)	multilayer networks	multilayer networks
13 (4/10 and 4/12)	assortativity	mixed random networks
14 (4/17 and 4/19)	centrality	structure detection
15 (4/24 and 4/26)	structure detection	structure detection
16 (5/1 and 5/3)	organizational networks	special topics

†: 3-4 minutes each + 1 or 2 questions;

Outline

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Projects

- Semester-long projects, teams (maybe multiple)
- Big themes: Stories, Narratives, and Language.
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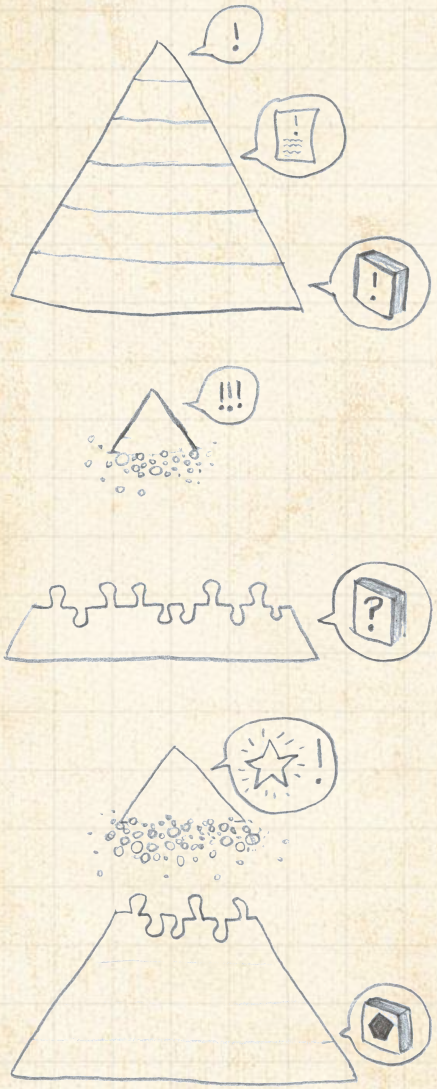
The narrative hierarchy—Stories and Storytelling on all Scales:



- 1 to 3 word encapsulation = a soundbite = a buzzframe,
- 1 sentence, title,
- few sentences, a haiku,
- a paragraph, abstract,
- short paper, essay,
- long paper,
- chapter,
- book,
- ...

Key Observation:

- Many complex systems
  can be viewed as complex networks
  of physical or abstract interactions.
- Opens door to mathematical and numerical analysis.
- Dominant approach of last decade of a theoretical-physics/stat-mechish flavor.
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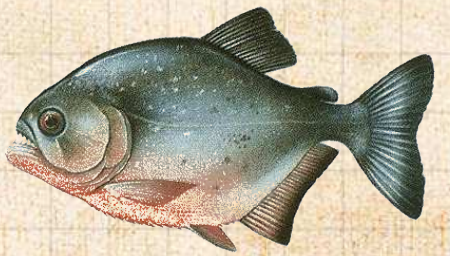

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- Hunt in packs.
- Feast on new and interesting ideas (see chaos, cellular automata, ...)

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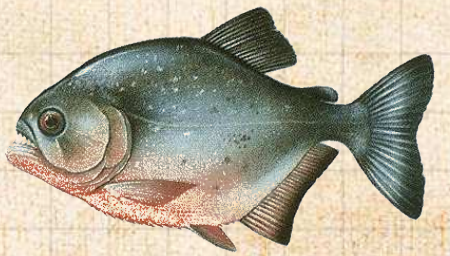

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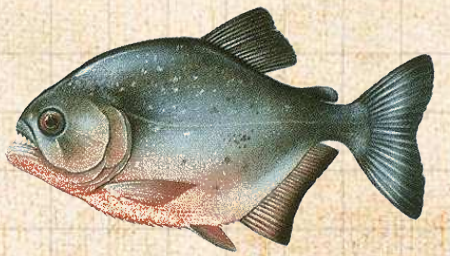

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THE MANIFESTO

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y=x^a
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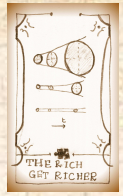
MINISTRY OF RANDOM WALKS

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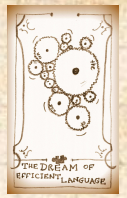
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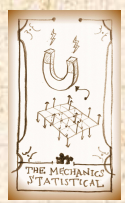
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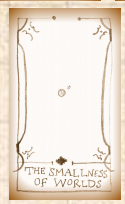
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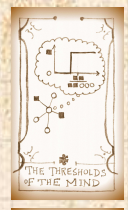
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THE END

"I am the Monarch of the Sea.."
N,m
THE ARK OF THE RANDOM NETWORK

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1. generalized random networks:
   - Arbitrary degree distribution P_k.
   - Wire nodes together randomly.
   - Create ensemble to test deviations from randomness.
   - Interesting, applicable, rich mathematically.
   - We will have fun with these things ...

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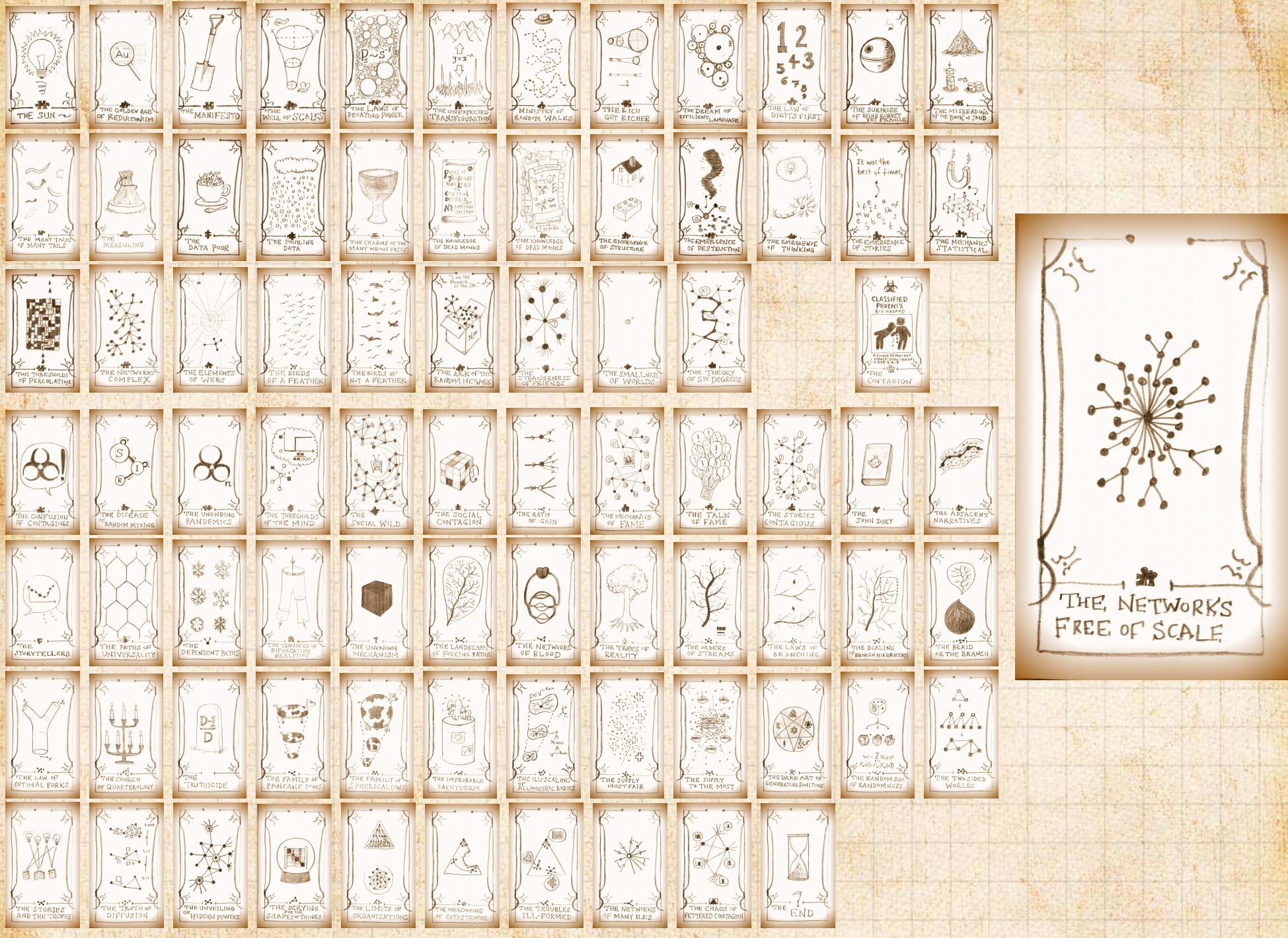
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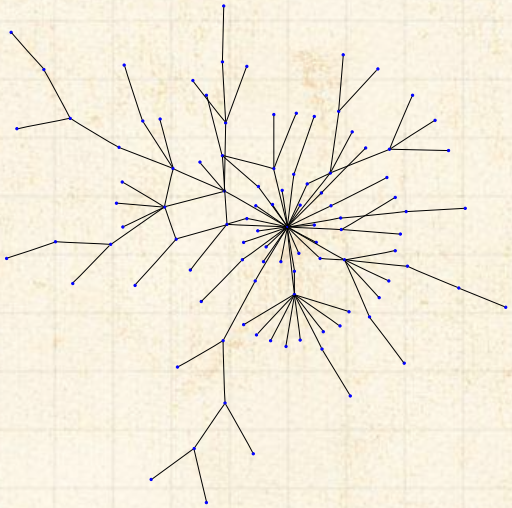

$\gamma = 2.5$, $\langle k \rangle = 1.8$, $N = 150$

- Introduced by Barabasi and Albert [3]
- Generative model
- Preferential attachment model with growth:
- $P[\text{attachment to node } i] \propto k_i^{\alpha}$.
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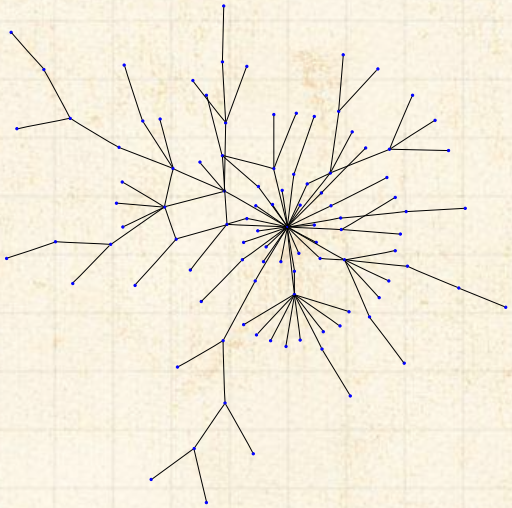

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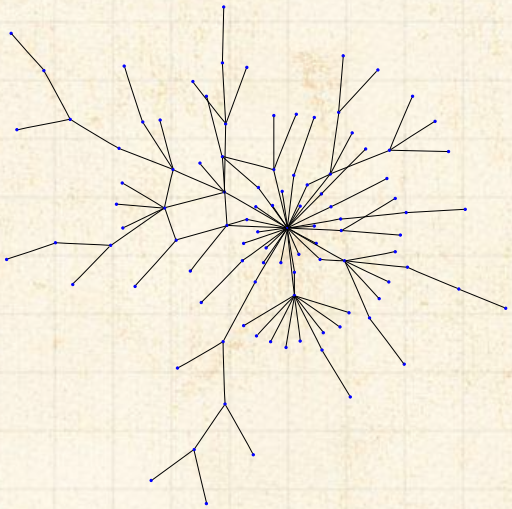

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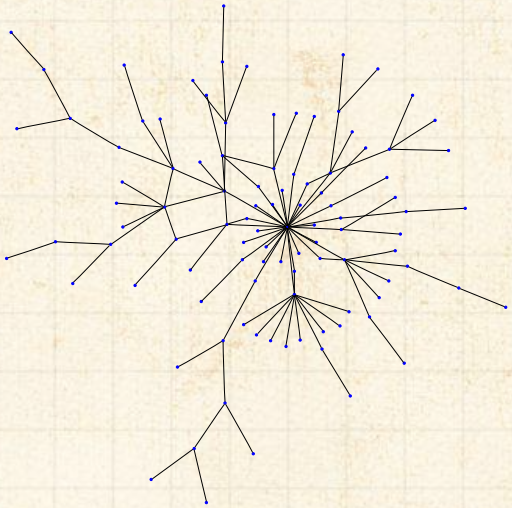

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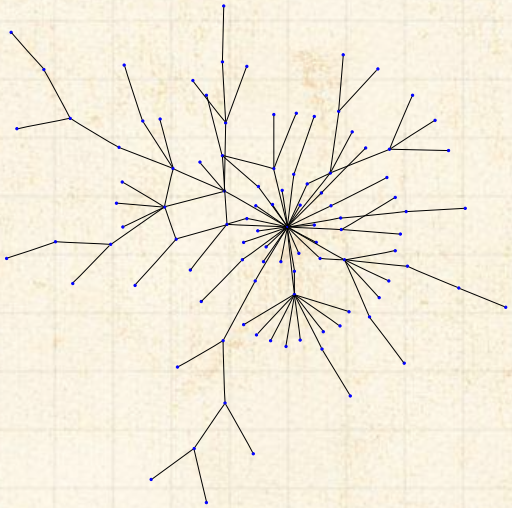

$\gamma = 2.5$, $\langle k \rangle = 1.8$, $N = 150$

- Introduced by Barabasi and Albert [3]
- Generative model
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- $P[\text{attachment to node } i] \propto k_i^{\alpha}$.
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- Trickiness: other models generate skewed degree distributions.

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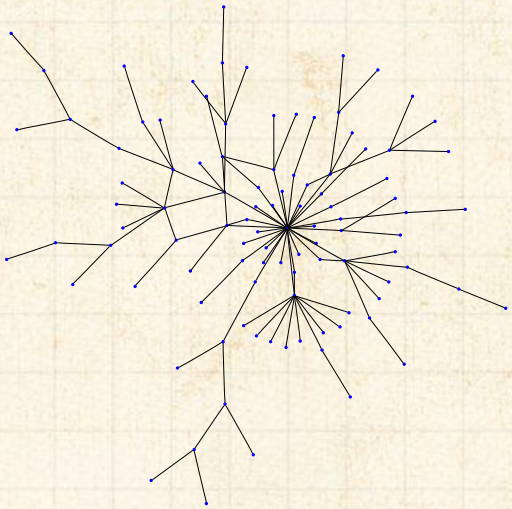

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THE SMALLNESS OF WORLDS

Models

3. small-world networks

- Introduced by Watts and Strogatz [10]
- local regularity (an individual's friends know each other)
- global randomness (shortcuts).
- Shortcuts allow disease to jump
- Number of infectives increases exponentially in time
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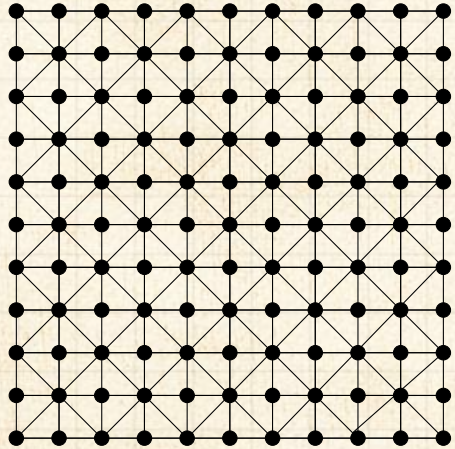

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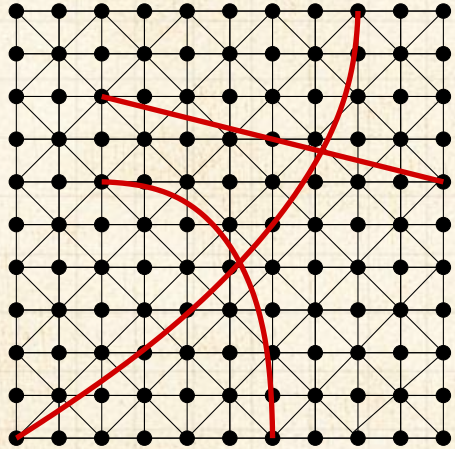

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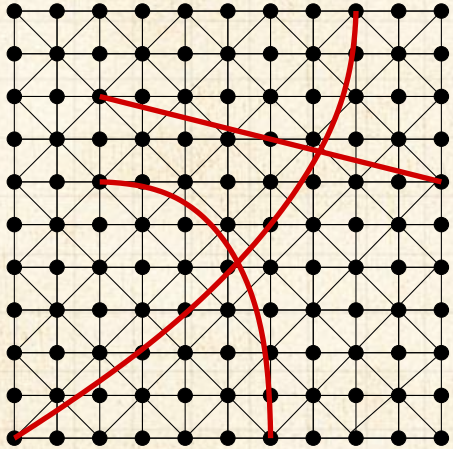

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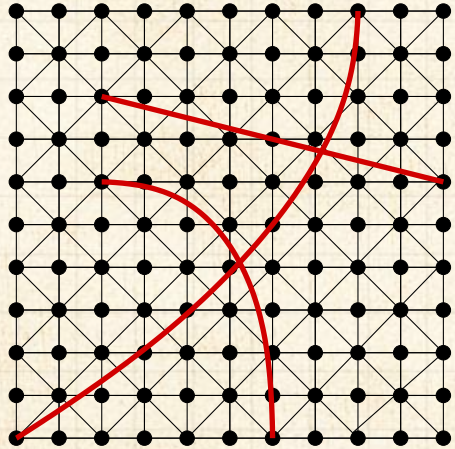

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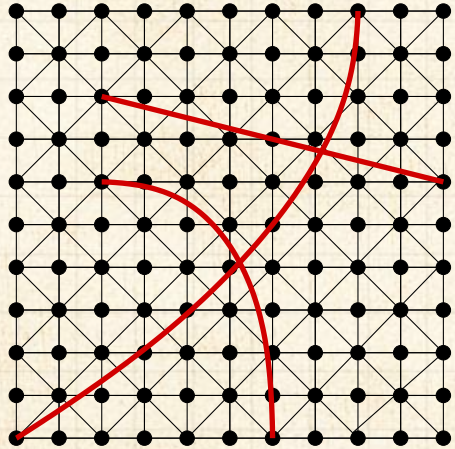

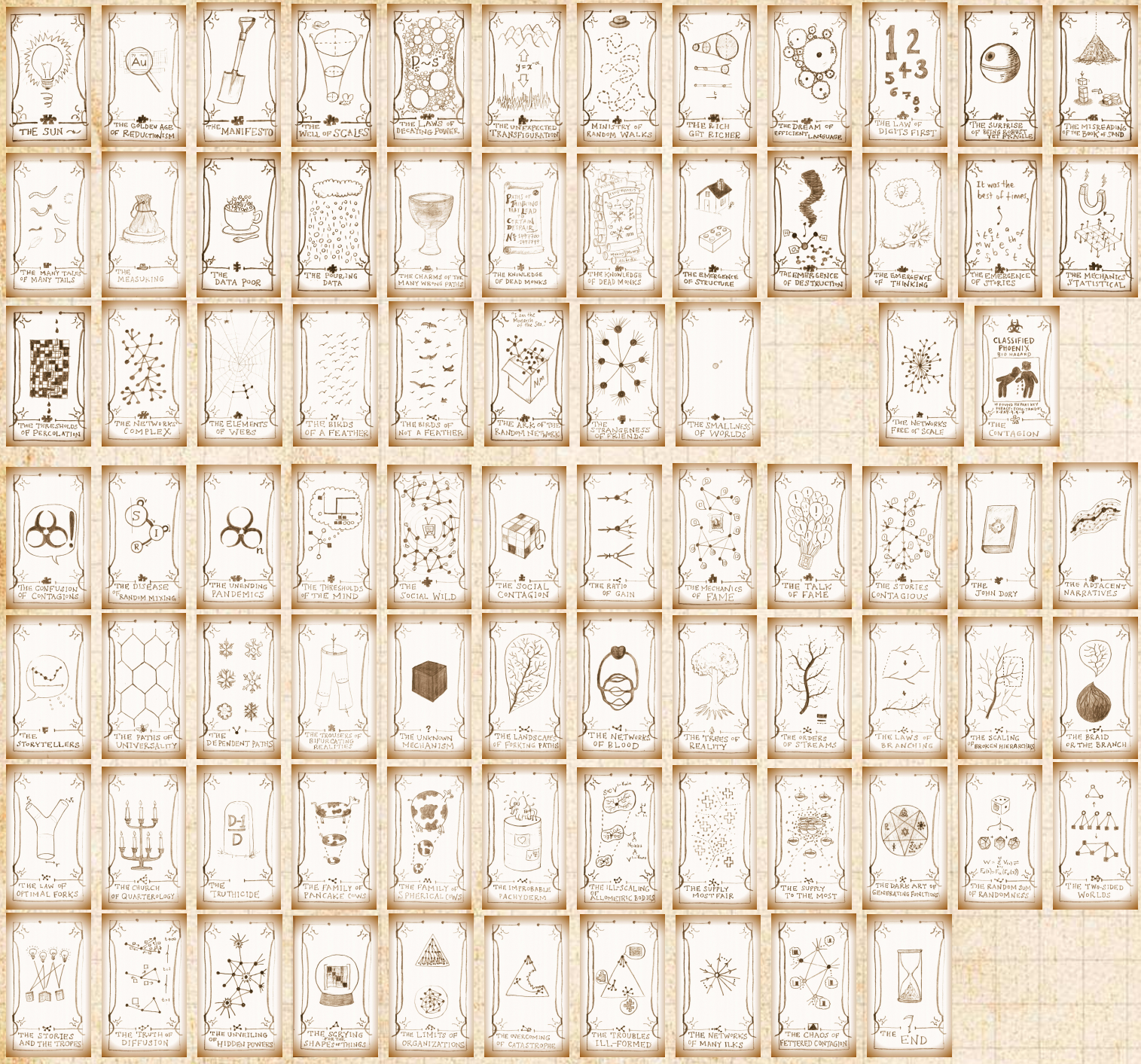
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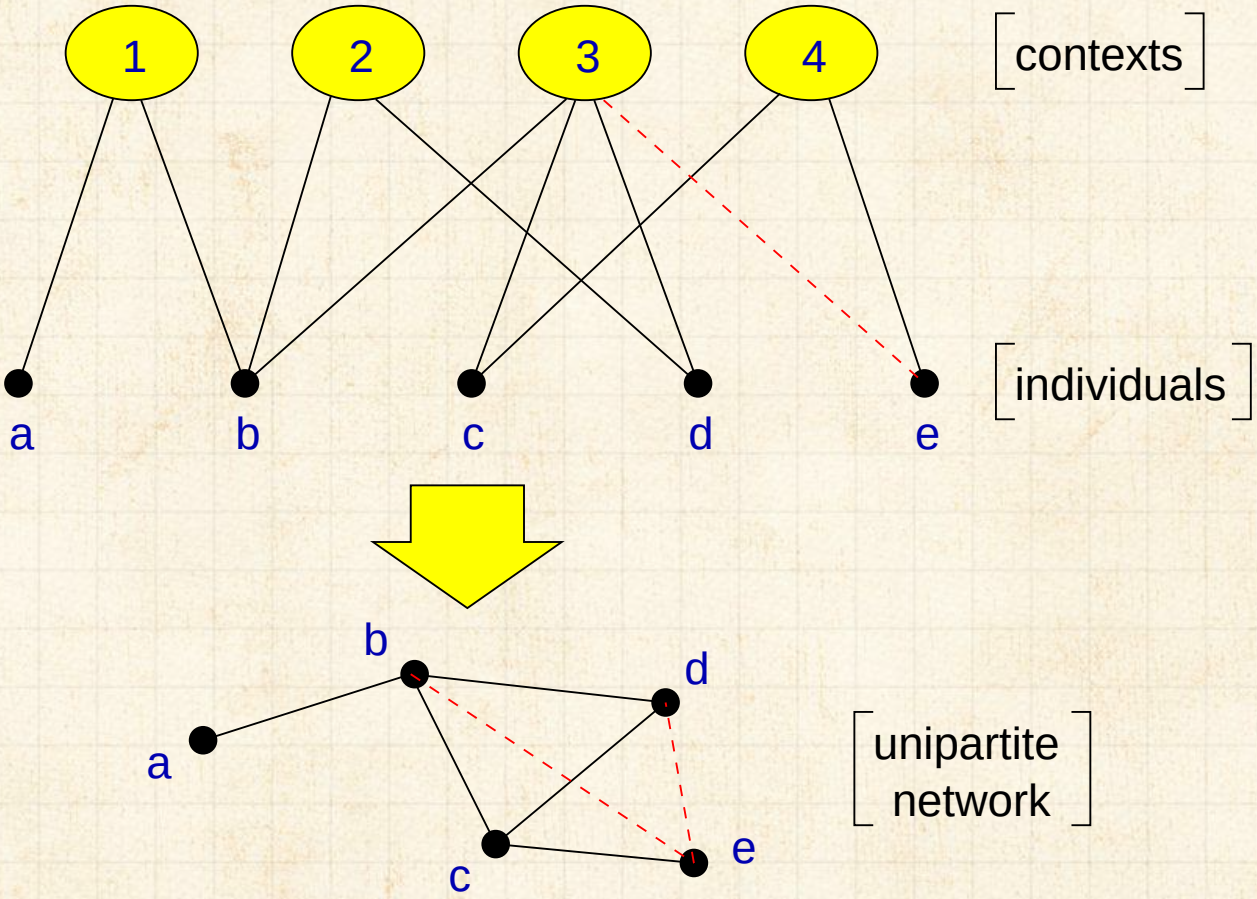
Models

5. generalized affiliation networks



Bipartite affiliation networks: boards and directors, movies and actors.

Models

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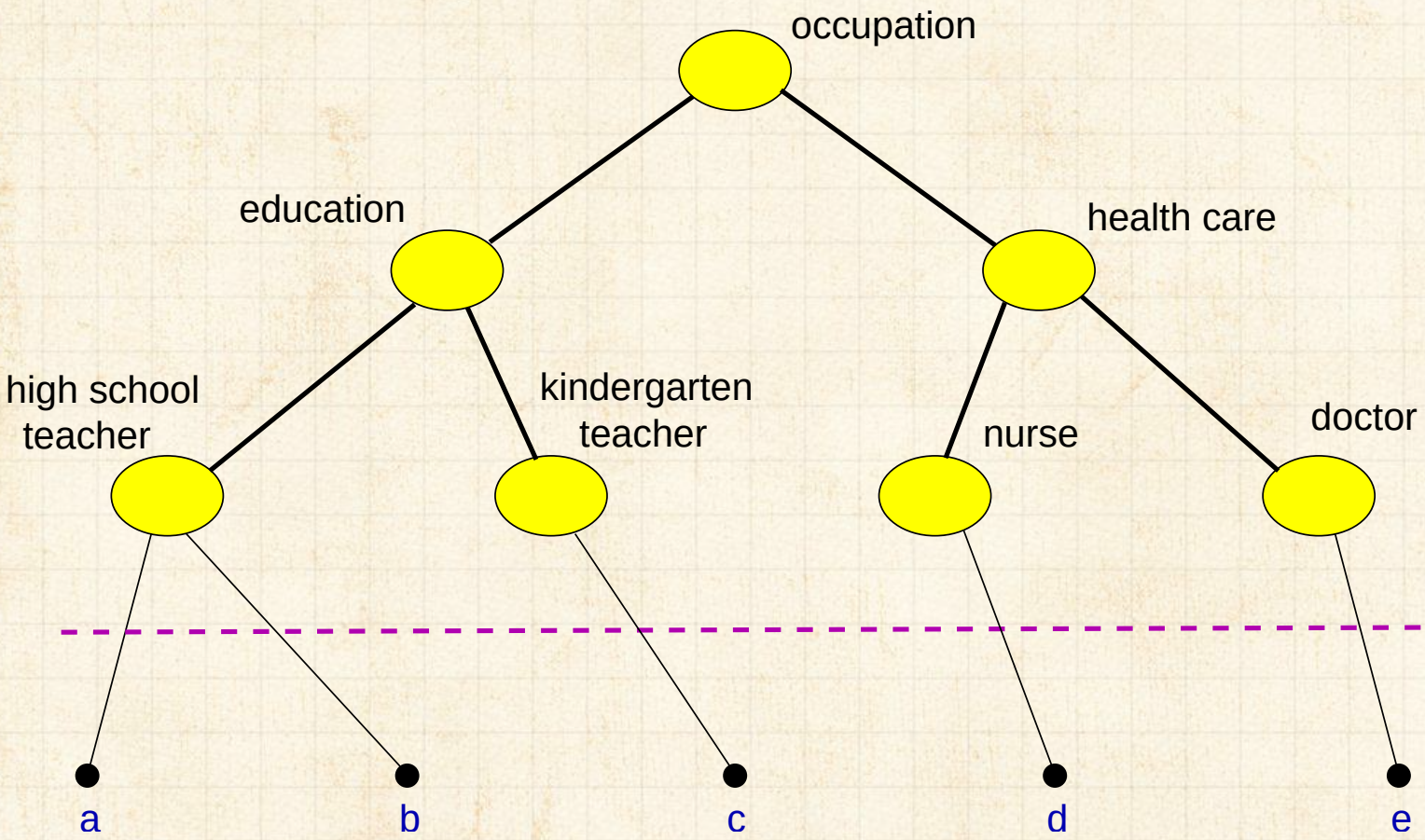

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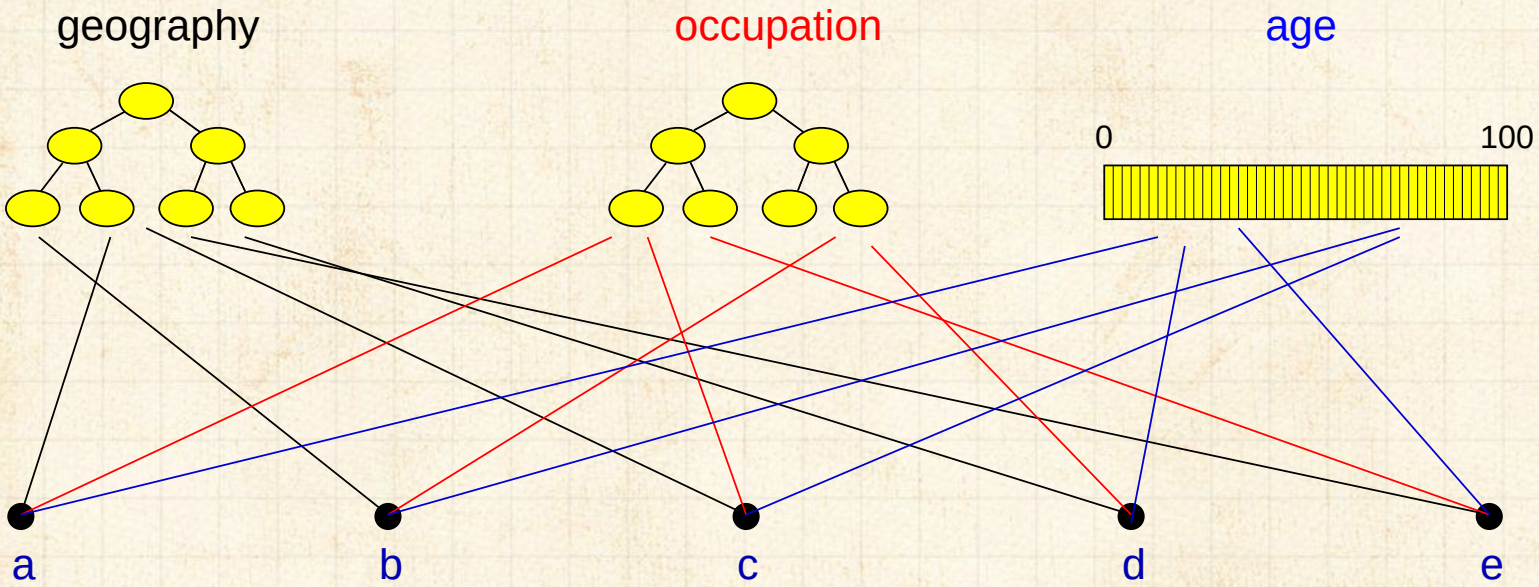

- Blau & Schwartz [4], Simmel [8], Breiger [6], Watts *et al.* [9]

Bonus materials:

Textbooks:

- Mark Newman (Physics, Michigan)
  "Networks: An Introduction"
- David Easley and Jon Kleinberg (Economics and Computer Science, Cornell)
  "Networks, Crowds, and Markets: Reasoning About a Highly Connected World"

Bonus materials:

Review articles:

- S. Boccaletti et al.,
  Physics Reports, 2006,
  "Complex networks: structure and dynamics" [5]
  Times cited: 7,897 (as of January 15, 2018)
- M. Newman,
  SIAM Review, 2003,
  "The structure and function of complex networks" [7]
  Times cited: 16,768 (as of January 15, 2018)
- R. Albert and A.-L. Barabási
  Reviews of Modern Physics, 2002,
  "Statistical mechanics of complex networks" [1]
  Times cited: 20,656 (as of January 15, 2018)

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Nutshell:

Overview Key Points:

- The field of complex networks came into existence in the late 1990s.
- Explosion of papers and interest since 1998/99.
- Hardened up much thinking about complex systems.
- Specific focus on networks that are large-scale, sparse, natural or man-made, evolving and dynamic, and (crucially) measurable.
- Three main (blurred) categories:
  1. Physical (e.g., river networks),
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  3. Abstract (e.g., thesauri).

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Overview Key Points (cont.):

- Obvious connections with the vast extant field of graph theory.
- But focus on dynamics is more of a physics/stat-mech/comp-sci flavor.
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  1. Description: Characterizing very large networks
  2. Explanation: Micro story $\Rightarrow$ Macro features
- Some essential structural aspects are understood: degree distribution, clustering, assortativity, group structure, overall structure, ...
- Still much work to be done, especially with respect to dynamics ... exciting!

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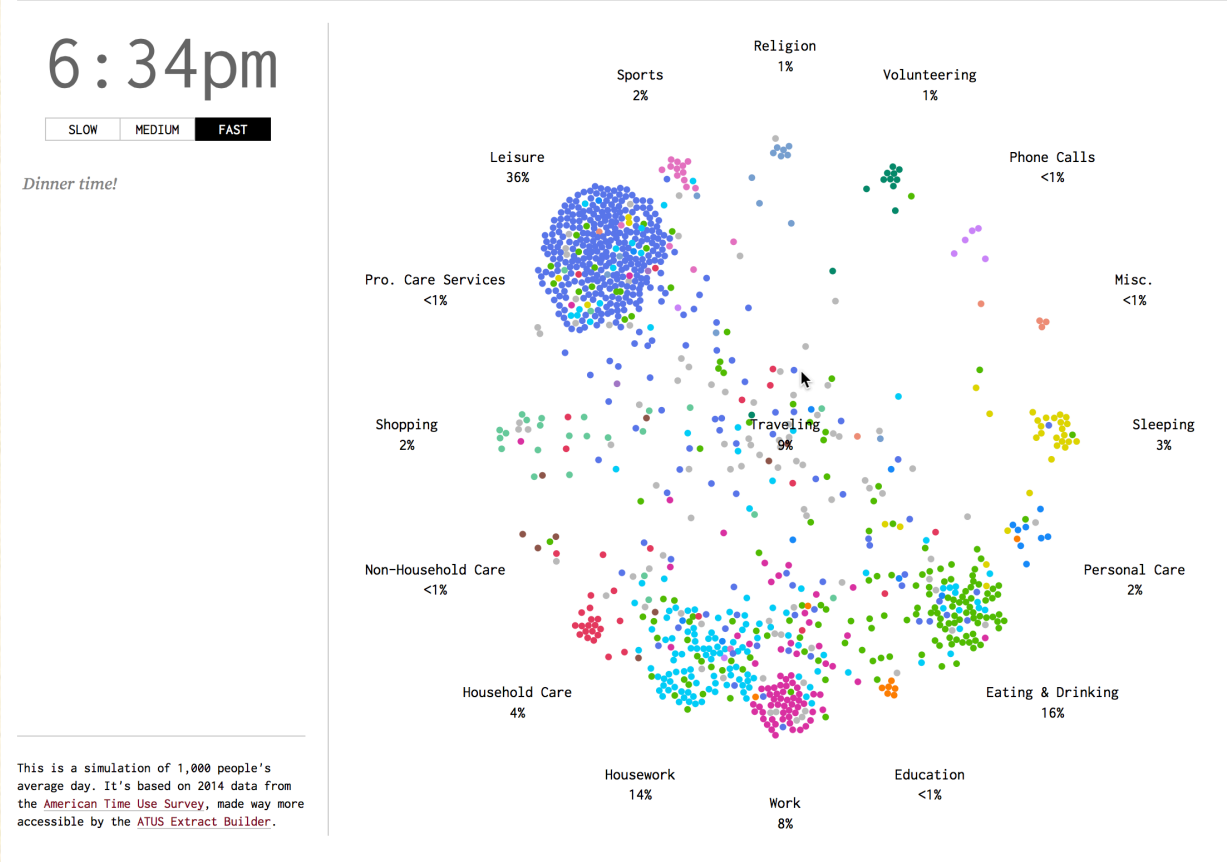
Neural solace—Temporal social networks:

Visualizing a day in the life of Americans



Source: Flowing Data/Nathan Yau.

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[3] A.-L. Barabási and R. Albert.
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Identity and search in social networks.
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[10] D. J. Watts and S. J. Strogatz.
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