Individual Reading Lists

Here are your reading lists. In general, I have kept the lists focused on central ideas and results that you should know for your academic focus, but the topics are still a random and sparse assortment (meant primarily as a supplement to the somewhat more systematic progression of the class notes). Some of you will have seen some of the articles and book references in your list. This is fine. If you would like additional suggestions, please come talk to me.

A one to two-page, double-spaced reflections paper over these readings will be due at the beginning of the last day of class. You can swap any of your readings with any others on the lists that look more interesting. Unless otherwise indicated, any paper or other material in SMALL CAPS is in the "Individual Readings" folder of the course folder. If you would like to discuss any of the readings with me, send me an email and we'll find a time to meet.

(compartmental models of epidemiology and related psychological phenomena)

a) The simplest compartmental models are nonspatial. Here are several references:
   HETHCOTE00, FUNK10, and as an example, CHOWELL07.
   Such models may be suitable for densely populated cities and quickly moving pathogens, but may be less accurate for slower pathogens and larger geographical regions.

b) Of the available *spatial* SI models, Mollison's dynamics may be more realistic for human epidemics than the more widely known and studied Fisher-Kolmogorov-Petrovsky-Piscounov (Fisher-KPP) systems:
   MOLLISON72_1 and MOLLISON72_1 (and forward citations), MARVEL13.
   Fisher-KPP equations still may be more accurate than Mollison dynamics for disease spreading through plant populations and possibly some animal populations, as well as wind-driven disease spreading.

c) Many basic questions regarding the spatial spread of modern epidemics remain unanswered. The seasonal flu constitutes an excellent example:
   EARN02.

d) 'Small-world' networks and other theoretical constructs may give a partial mechanistic explanation for the rapid spread of modern epidemics:
   BALL97, WATTS98, NEWMAN99, BARBOUR01, NEWMAN02.

e) In the last decade, large high-quality data sets have enabled empirical characterizations of human mobility and the spatial spread of common diseases (like the flu):
   BROCKMANN06, GONZALEZ08, SONG10, CHO11, RHEE11, NOULAS12, SIMINI12, HUFNAGEL04, FERGUSON06, RILEY07, MOSSONG08, BALCAN09, MERLER10.

(auto buyer preferences)

a) Here are several references on cultural dissemination and opinion dynamics:
   AXELROD97 (a foundational paper), CENTOLA07, CENTOLA10, MARVEL12.

Research in these areas focuses on how opinions and practices of individuals can change over time as people surround themselves with others similar to themselves (*homophily*) and are in turn influenced by these affiliations (*social influence*). Other models of opinion dynamics are mentioned in Section III of

Castellano09.

b) If you haven't done so already, familiarize yourself with constructs that combine deterministic and random components, like Kalman filters (i.e. dynamics of moments), the Fokker-Planck equation, and transformations of random variables. One simple (perhaps too simple) introduction to Kalman filters is

Maybeck79.

An intuitive derivation of the Fokker-Planck equation is given in XIV.6 of Feller (1968, vol. 1, 3rd ed.). A primer on transformations of random variables is given in 2.1 of Casella (2002, 2nd ed.). You might also look up the Langevin equation and continuous-time stochastic dynamics, like the Wiener process (although probably more for simulation than analysis). One easily readable paper that discusses a computational framework for finding nonlinear dynamics from time series data is:

Schmidt09.

c) Acquire cocktail party proficiency in Blau spaces and dynamics on them. Michael Macy (`sdl.soc.cornell.edu/mwm`) has a current interest in this area. Here is an introduction to the notion of Blau spaces (really a trivial construct):

McPherson04.

For the basic non-academic formulation of the idea, you can just see Wikipedia articles like "Blau space," "Liberal elite," "*Talking Right*" and similar. There is relatively little literature on dynamics on Blau spaces. You could be a pioneer in the area.

d) I would also recommend carefully evaluating what sorts of data can be obtained from the many national and international agencies that collect information on the auto industry. With a few Google searches, I was easily able to find certain limited time series data.

(applications in biostatistics)

a) For high dimensional biochemical systems (e.g. inside a cell or within a section of tissue), the state of the system often moves quickly to a low dimensional 'surface' (formally called a *manifold*) and then moves slowly along this surface. This is one reason why we can often approximate and analyze high dimensional systems with low dimensional dynamics. Two of the best explained examples of such *fast-slow systems* are given in 3.5 and 7.5 of the Strogatz text. Be sure to read these carefully and work through the relevant calculations.

b) Look into the idea of sloppiness, which appears frequently in systems biology, and learn how to use the Hessian matrix to evaluate it:

Gutenkunst07_1, Gutenkunst07_2.

c) There is a neat body of literature on network motifs, particularly for gene networks, that you might find interesting. Here are two papers from Uri Alon in this area:

Milo02, Milo04. (These ideas seem relevant for Tong04, Li04 for example.)

d) Beautiful scaling laws hold across the animal kingdom. The primary paper on this is
West97.

(theoretical cosmology, fluid dynamics, condensed matter physics, field theories)

a) If you don't yet have a copy of Landau and Lifshitz's *Mechanics* (3rd ed., Vol. 1), I would recommend acquiring one and reading at least the first two chapters. The slim book is a review of classical mechanics but with a clarity and emphasis on symmetry that can best be appreciated from a perspective well beyond it (where you are now).

b) If you are not already familiar with Kolmogorov-Arnold-Moser theory, you'll want to read
Henon83.
(Ask me for a paper copy—this reference is not in the online folder and is hard to find.) In dynamical systems, Michel Hénon is famous for the Hénon map.

c) Renormalization group is of course central to several areas of physics. Sadly, this summer saw the death of one of its founders, Kenneth Wilson, who was awarded a Nobel prize for his work on the topic. I do not have excellent introductory paper references on renormalization, but both *Renormalization Methods* by William David McComb (included in the folder), and *Lectures On Phase Transitions And The Renormalization Group* by Nigel Goldenfeld seem acceptable for someone with a strong physics background.

d) Synchronization also appears widely in physical systems. It is often qualitatively modeled using *coupled oscillator systems*. One mathematically tractable member of this family of systems and one of the earliest to be studied is the *Kuramoto model*. For an expository introduction to some of the unexpected instances of synchronization in physics, see the chapter, "Quantum Choruses," in Strogatz's book, *Sync*. (Also see me for a paper copy of this.) More technical treatments of the topic include
Strogatz00, Acebron05.

(broad interests in global trade networks, environmental systems, multi-agent systems)

a) Here is an engaging paper by César Hidalgo on the connection between the development of an economy and the diversity of products it produces:
Hidalgo09.

b) Power laws are pervasive in economics. An excellent field-specific primer on the mechanisms behind their appearance is
Gabaix09.

c) A large body of behavioral economics literature has emerged in the last three decades on strategies for playing the Prisoner's Dilemma game, which some regard as a minimal game-theoretic model for many of the choices that we make in the context of our social communities. The article that started the revolution is
Axelrod83.
Notice Axelrod's playful methodology in this paper. Recent work in the field has been sim-

ilarly oriented toward conducting experiments. See for example the work of David Rand (`daverand.org`). Fehr and Gächter also published an article on punishment that has been influential across several fields over the last decade:
FEHR02.

d) Finally, on the expository end, here is a popular press piece (which came out during the trough of the financial crisis) arguing that banking systems and ecosystems may have overlapping challenges:
MAY08.
The flavor is characteristic of the ethos of complex systems.

For these suggestions, I have assumed that you have a focus on trade and economics. For social and environmentally-related papers, see part (a) of ’s and ’s lists.

(computer science and economics)

I sense that your interests are diverse and possibly somewhat theoretical. Look over the other nine reading lists and see if you find articles that interest you. ’s and ’s lists might be particularly relevant. If you would like additional ideas, come see me.

(engineering-oriented computer science)

a) As you might have guessed, I would point you to Liz Bradley’s work on analyzing computers as nonlinear systems:
`cs.colorado.edu/ lizb/computer-dynamics.html`,
`cs.colorado.edu/ lizb/papers/dos.html`.

b) If you have not studied information theory, you should check out the original paper by Claude Shannon, which is surprisingly readable and includes almost all of the major results of the field:
SHANNON48.

c) The study of complex systems often includes material on computability theory and aspects of computational complexity. Everyone has their favorite authors for this. I like the third edition of *Computability and Logic* by Boolos and Jeffrey (but not earlier or later editions).

d) Depending on your research interests, Kolmogorov complexity may also be a relevant topic for study—it strives to quantify the complexity of individual strings of symbols (e.g. 0101010101 . . . is simple and 0110101110 . . . is intuitively complex). The best single-paper introductions in my files are:
MARTINLOF66, LIVITANYIXX.
However I personally prefer *An Introduction to Kolmogorov Complexity and Its Applications* by Ming Li and Paul Vitányi.

(diverse interests in chemistry, physics, and mathematical logic)

a) If you have a focus on the dynamics of chemical systems, you should look into Feinberg’s deficiency one and deficiency zero theorems (sometimes referred to as “deficiency theory”). Unfortunately, there are few simple introductory treatments of the topic. The best materials that I am aware of are

Feinberg87, Feinberg88, Guberman03, Shinar10.

b) Although we do little with partial differential equations in class, you should be aware of reaction-diffusion equations and their (putative) role in pattern formation in biology. Mathematically, they have the form, $u_t = u_{xx} + f(u)$, where f is a function of $u(x,t)$. The original paper that introduced them was by Alan Turing (the Turing you know):

Turing52.

Simple reaction-diffusion equations are able to produce patterns of exquisite complexity—in many cases very similar to those in nature. For a few visual examples, see

ReactionDiffusionSlide (my own slide; the papers cited are not in the folder).

Reaction-diffusion equations are also thought to be responsible for the complexity that we observe in embryogenesis and other intervals of developmental biology where segmentation and other spatial differentiation emerges in what initially appears to be homogeneous tissue.

c) Be aware of stochastic master equation formulations, which do appear in some chemistry literature. In general, these can be used to circumvent some of the failures of deterministic nonlinear dynamics (e.g. the law of mass action) in approximating fundamentally stochastic processes. Perhaps the easiest way to get a basic understanding of master equations is to work through an example. Here is a paper with one for a social system:

Xie11.

Derive the master equation (Eq. 2) in this paper from the assumed dynamics (Table 1). Since the terms of the dynamics are quadratic, the process of deriving a master equation for a chemical system is analogous. The utility of the master equation approach is broadly explained for the reaction $\mathrm{A} + \mathrm{A} \to \mathrm{B}$ by

Doi76.

d) You should acquaint yourself with *fast-slow systems* and *canards*. For high dimensional chemical systems (e.g. systems with many different concentrations changing over time), the state of the system often moves quickly to a low dimensional ‘surface’ (formally, a *manifold*) and then moves slowly along this surface toward a limit set. It is because of this that we can often approximate and analyze high dimensional systems with low dimensional dynamics. Two of the best explained examples of fast-slow systems are given in 3.5 and 7.5 of the Strogatz text. Read these carefully and work through the calculations.

These suggestions assume that your interests lie mostly in chemistry. If you also have interests in physics, check out 's list.

(sustainable systems, cities, and transportation)

a) Here are two articles with overlapping content that give a neat series of figures showing in quantitative terms the development of different modes of transportation over the last 200 years (the only such resource that I have found):

Ausebel98_HTML (alternatively, Ausebel98_PoorPhotocopy), Ausubel01.

b) Here are two articles by Bettencourt, West and coauthors describing scaling in cities:
   Bettencourt07, Bettencourt10.
   In addition, here is a recent article from César Hidalgo on the perception of inequality in cities (in case this sort of thing is of interest to you):
   Salesses13.

c) There is also a great deal of recent literature on human mobility, which gives another window into the patterns of human transportation in urban and rural areas:
   Brockmann06, Gonzalez08, Song10, Cho11, Rhee11, Noulas12, Simini12.

(biomechanics and mechanical engineering in biology)

a) There is fascinating literature on animal gaits viewed through the lens of dynamical systems. If I haven't exhausted your appetite for Strogatz, see the popular press piece:
   Strogatz93.
   Then see the final citation of this article:
   Collins93.
   Here is another more computational approach on the same topic:
   Srinivasan06.
   For an approach that includes neural input, see
   Sherwood11.
   For a recent study of the dynamical effect of leg amputations on human running, see
   Look13.

b) There is also a rich and growing literature on insect flight. Here are several examples:
   Wang05 (a review), Ristroph09, Bergou10.

c) There are strikingly well-behaved allometric scaling laws in biology:
   West97.
   (Remarkably, similar scaling also applies in cities:
   Bettencourt07, Bettencourt10.)

d) On the scale of the cell, there are many interesting results from biomathematics. Here is an article that represents creative thinking about cell packing structure in proliferating epithelia:
   Gibson06.
   This is representative of complex systems in that it focuses on mechanism and requires only minimal input from the underlying biological processes. As another example of cross-domain thinking, here is an article that applies methods from the study of random sequential absorption to give an elegant analysis of the dynamics of a biomolecular ratchet:
   D'Orsogna07.

All

Here are several broader references on the study of complex systems:
Newman11, Shalizi06, *Phase Transitions* by Ricard Solé.