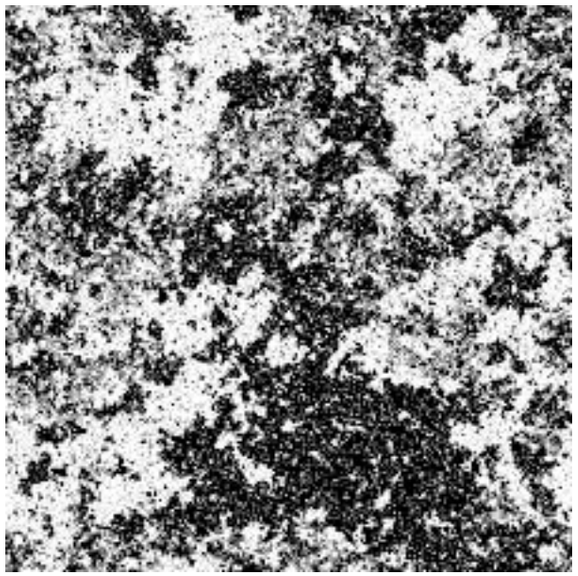
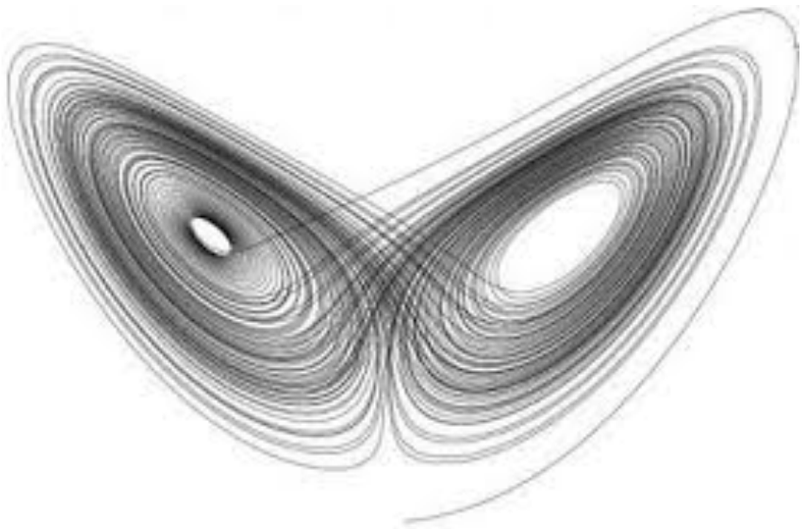
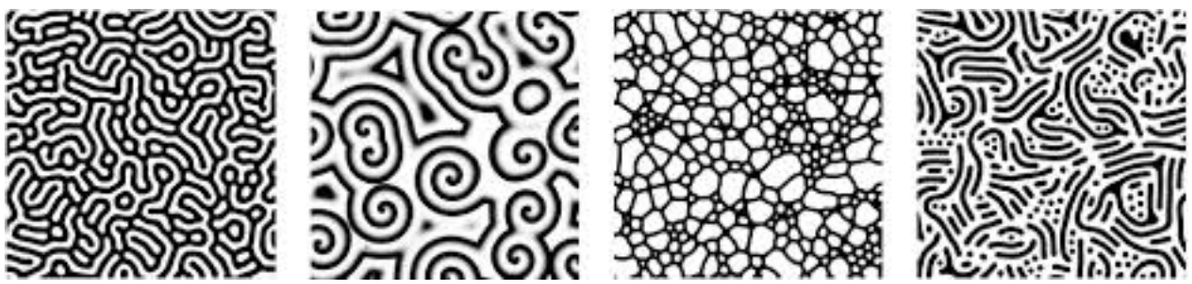
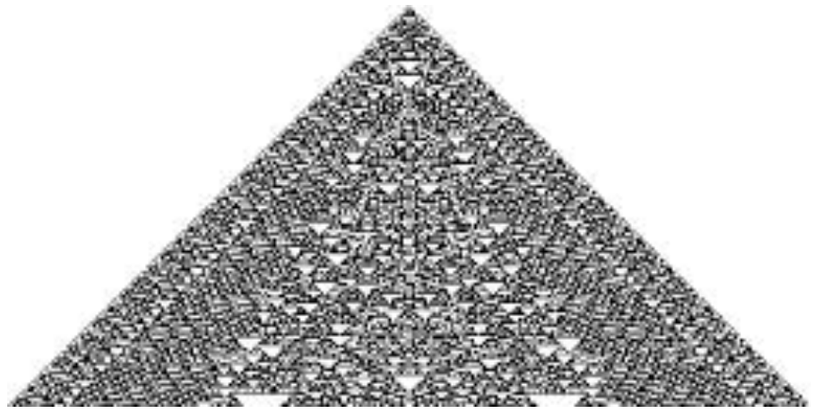
PHY 314 Introduction to Computational Physics









Dr. Dylan McNamara

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- Our interest is in **Dynamics**

Late 1600s	Newton	Calculus, planetary motion
Late 1800s	Poincare	Geometric approach, chaos hints
Early 1900s		Nonlinear oscillators (radio, radar, laser)
Early to mid 1900s	Birkhoff, Kolmogorov, Moser	Complex behavior in Hamiltonian mechanics
1963	Lorenz	Chaos in weather
1970s	May, Feigenbaum, Takens, Mandelbrot	Maps, universality, turbulence, fractals

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- **Dynamics** - Differential equations and iterated maps
- Simple harmonic oscillator as a system of eqs
- Nonlinearity
- Geometric view (phase space)

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Number of variables →

	$n = 1$	$n = 2$	$n \geq 3$	$n >> 1$	Continuum
Linear	*Growth, decay, or equilibrium* Exponential growth RC circuit Radioactive decay	*Oscillations* Linear oscillator Mass and spring RLC circuit 2-body problem (Kepler, Newton)	Civil engineering, structures Electrical engineering	*Collective phenomena* Coupled harmonic oscillators Solid-state physics Molecular dynamics Equilibrium statistical mechanics	*Waves and patterns* Elasticity Wave equations Electromagnetism (Maxwell) Quantum mechanics (Schrödinger, Heisenberg, Dirac) Heat and diffusion Acoustics Viscous fluids
↓ Nonlinearity			*The frontier*		
Nonlinear	Fixed points Bifurcations Overdamped systems, relaxational dynamics Logistic equation for single species	Pendulum Anharmonic oscillators Limit cycles Biological oscillators (neurons, heart cells) Predator-prey cycles Nonlinear electronics (van der Pol, Josephson)	*Chaos* Strange attractors (Lorenz) 3-body problem (Poincaré) Chemical kinetics Iterated maps (Feigenbaum) Fractals (Mandelbrot) Forced nonlinear oscillators (Levinson, Smale) Practical uses of chaos Quantum chaos ?	Coupled nonlinear oscillators Lasers, nonlinear optics Nonequilibrium statistical mechanics Nonlinear solid-state physics (semiconductors) Josephson arrays Heart cell synchronization Neural networks Immune system Ecosystems Economics	*Spatio-temporal complexity* Nonlinear waves (shocks, solitons) Plasmas Earthquakes General relativity (Einstein) Quantum field theory Reaction-diffusion, biological and chemical waves Fibrillation Epilepsy Turbulent fluids (Navier-Stokes) Life

Table from Strogatz

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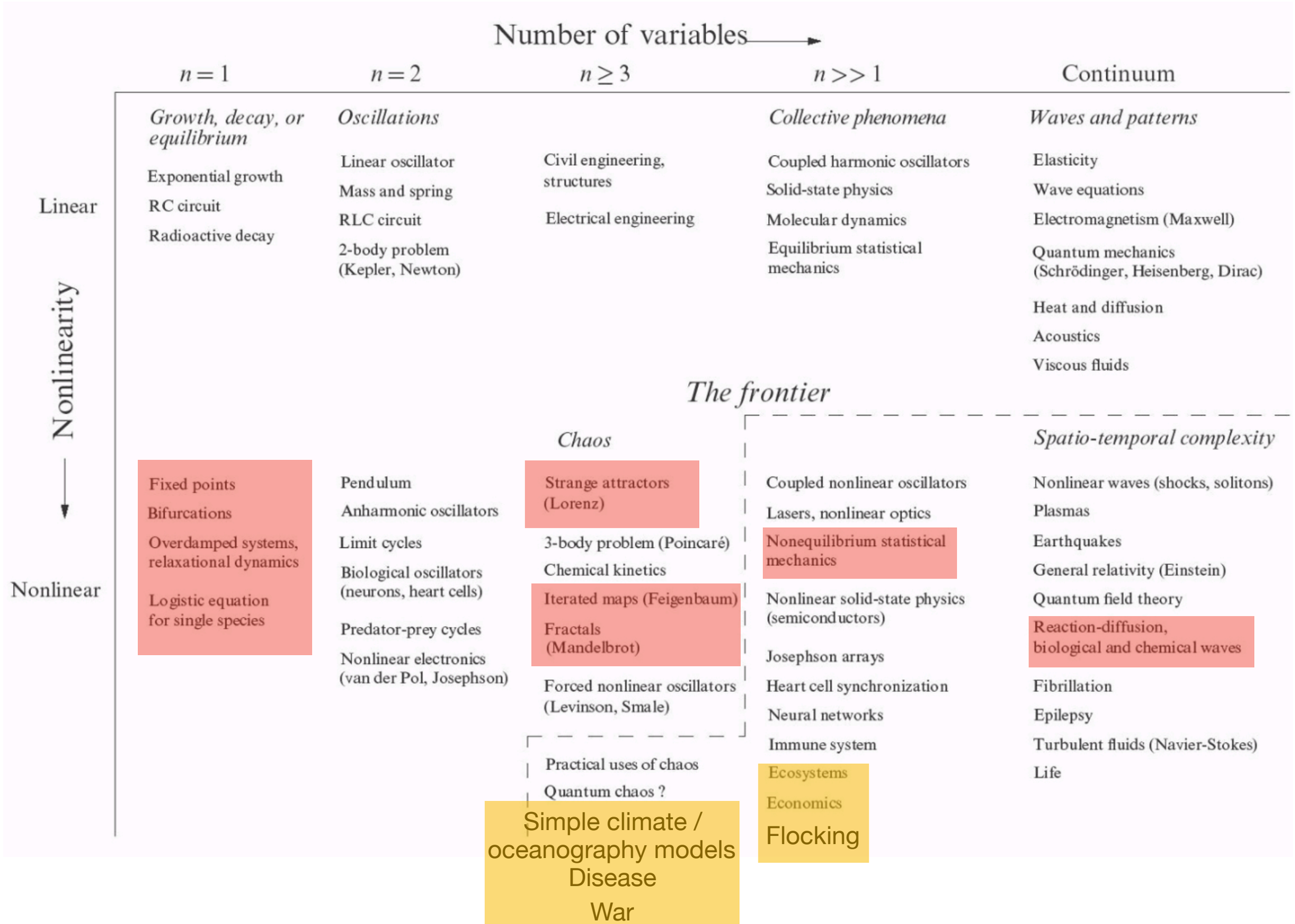

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- General programming languages

  ➡ C, C++, Java, Python, Fortran, R, etc…

- Commercial languages

  ➡ Matlab, Mathematica, etc…