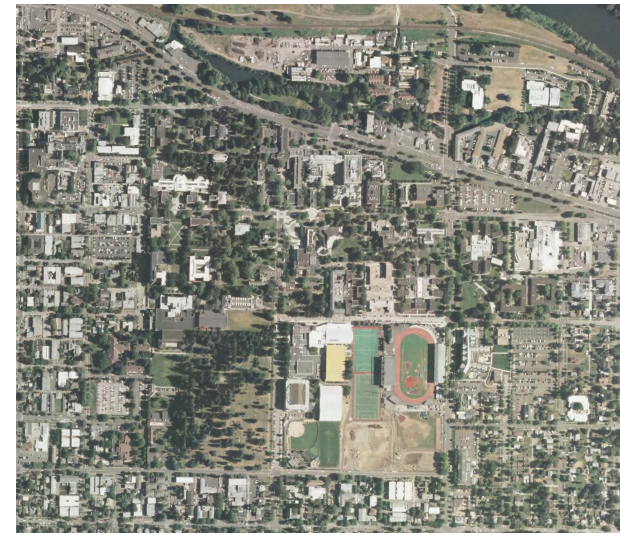# Lecture 8: Path Dependence

1936

1977

2005

Eugene, Oregon

Quick detour: clarification from last lecture...
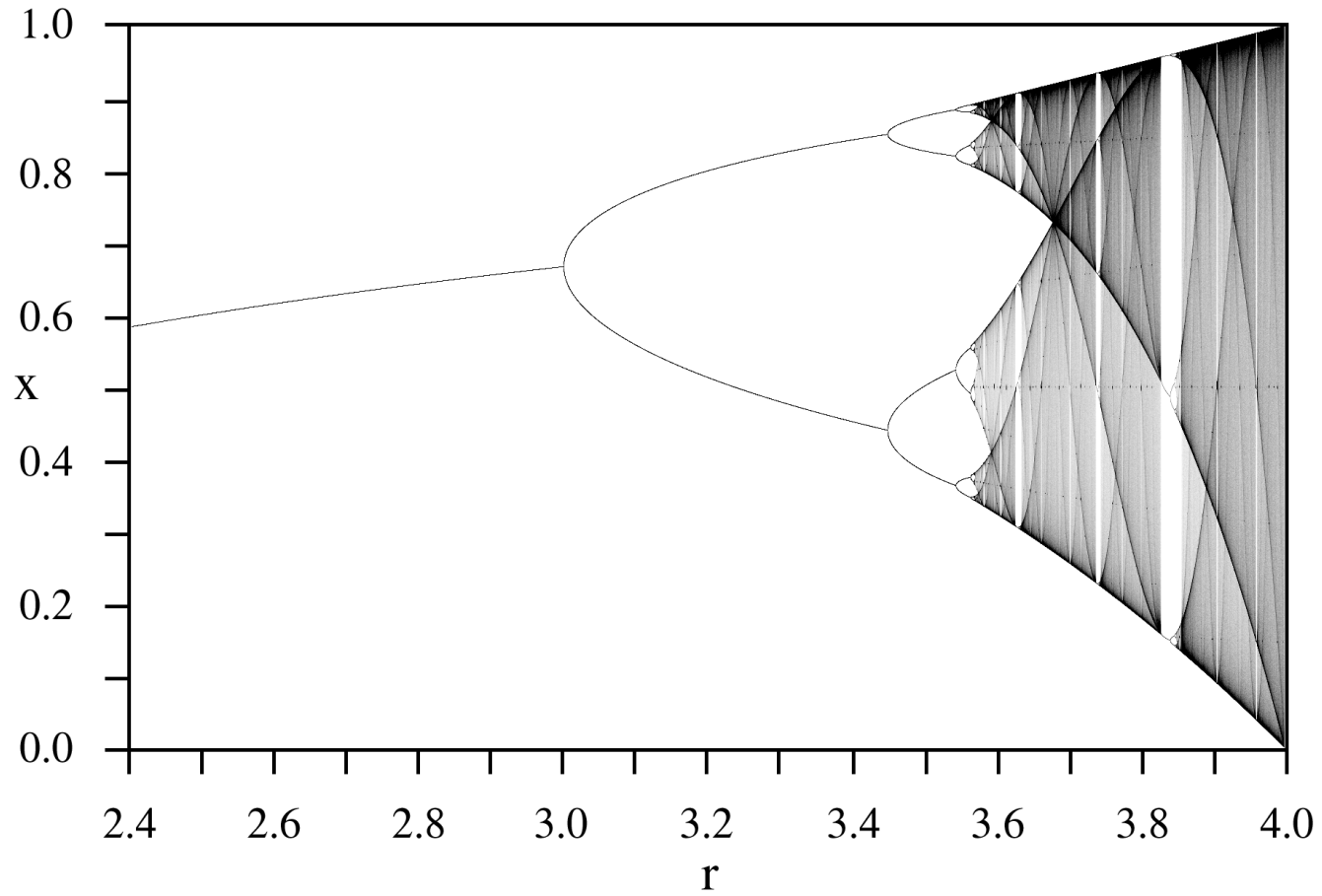
- Stochasticity and Uncertainty

Deterministic and Stochastic Processes/Phenomena

- Examples

Uncertainty

- Experimental Error
  - Measurement error
  - Statistical power issues
- Incomplete Knowledge of System
- Epistemological Uncertainty
  - Laplace's Demon
  - Quantum mechanics?

Chaos

Chaos

- Dynamical systems
- Completely deterministic
- Unpredictable outcomes (!)
- Outcomes can be indistinguishable from random
- Sensitive dependence on initial conditions
  - "Butterfly effect"
  - "impossible precision" needed for prediction
- http://www.complexityexplorer.org/
- http://experiences.math.cnrs.fr/

Uncertainty in Models

- Parameter Values

- Assumptions

- Abstractions

- Simplifications

Stochasticity in Models

- Probabilistic Outcomes
  - Decisions
  - Parameter values
- Randomization
  - "Random" number algorithms
  - `ask turtles […], ask patches […]`

Path Dependence

- "History Matters"
- Brown et al., 2005:
  - "Path dependence arises from negative and positive feedbacks."
- Inherently temporal
- Early events narrow the range of future possibilities.

Path Dependence

- Three types (definitions from economic modelers):
  - First degree: multiple (optimal) possible paths, perfect information
  - Second degree: imperfect information, path chosen may turn out to be suboptimal
  - Third degree: perfect information, chosen path is suboptimal, inefficiency

Some fun examples of path dependence…

# Where are you sitting?

Economics/Product Design

- VHS vs. Betamax

- HD-DVD vs. Blu-ray

- QWERTY keyboard

Morphogenesis

- [Turing, A. M.](#) (1952).
  ["The Chemical Basis of Morphogenesis"](#) (PDF).
  Philosophical Transactions of the Royal Society of London **237** (641): 37–72

- Reaction-Diffusion models

- https://pmneila.github.io/jsexp/grayscott/

Biological Evolution

- Codons: genetic dictionary
  - Nucleotide sequence to amino acid sequence
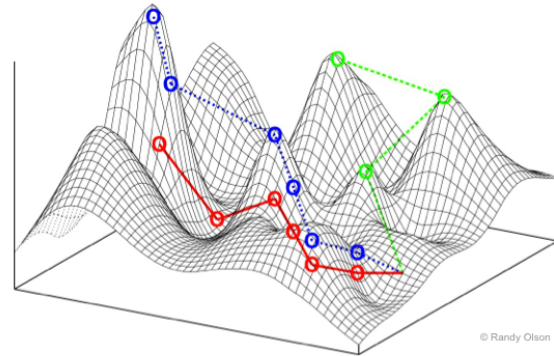

commons.wikimedia.org
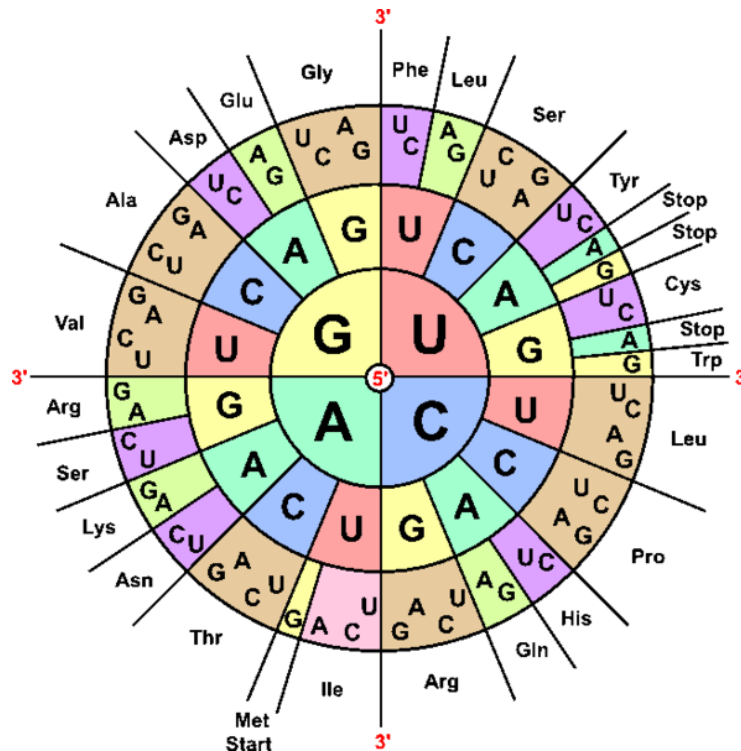
Fitness Landscapes

- Sewall Wright
  - "The roles of mutation, inbreeding, crossbreeding, and selection in evolution".
    Proceedings of the Sixth International Congress on Genetics
- Multiple Peaks

Fitness

Trait value
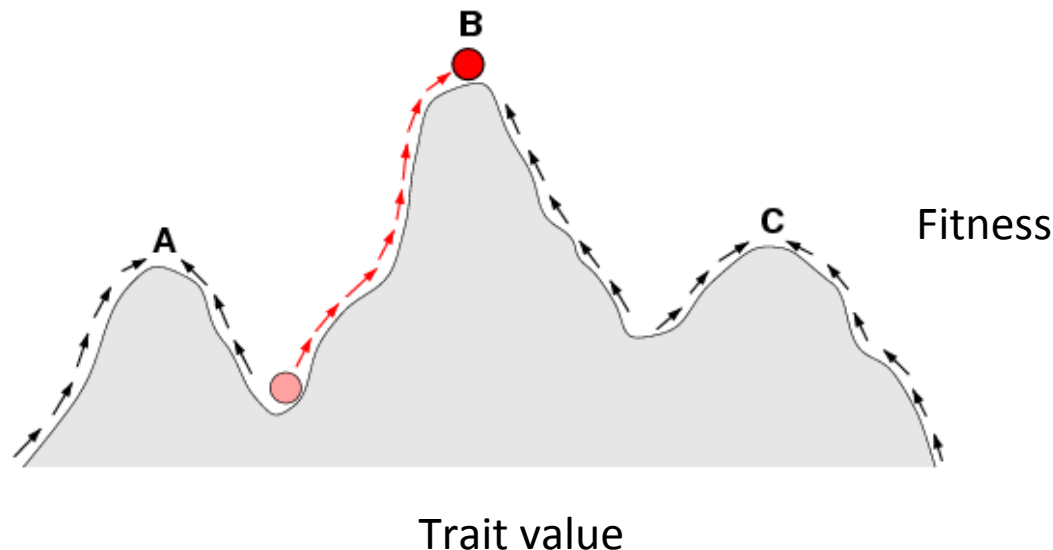
Fitness Landscapes

- Dynamic
- Multidimensional

© Randy Olson

en.wikipedia.org

Classification/Optimization Algorithms

- Markov Chain Monte Carlo
- Emergent Software
- Genetic and evolutionary algorithms
- Simulated evolution
  - Fitness functions

Others

- Language evolution?
- Culture?

Spatial Models: Path Dependence, Stochasticity and Uncertainty

- Brown et al, 2005:
  - "Many models, therefore, produce varying results because of **stochastic uncertainty** in their processes."
- Prediction?
  - Aggregate similarity
  - Spatial similarity
- Overfitting

- explain (not predict)
- guide data collection
- illuminate core dynamics
- suggest dynamical analogies
- discover new questions
- promote a scientific habit of mind
- bracket plausible range of outcomes
- illuminate uncertainties
- offer crisis options in near-real time
- demonstrate trade-offs
- challenge prevailing theories
- expose conflict between knowledge and data
- train practitioners
- discipline policy dialogue
- reveal the simple to be complex

Lab/Brown et al. Model

- Pitfalls/pointers?
- Heterogeneity?
- Utility function?
- Stochasticity?

Brown et al. Model

- What were the authors' 2 hypotheses?

Brown et al. Model

- What were the authors' 2 hypotheses?
  - "Our first hypothesis was that a model (and a system) with more and stronger feedbacks would be more path dependent than a model with fewer and/or weaker feedbacks"
  - "Our second hypothesis was that where the environment is relatively homogenous, land-use histories would be more path dependent than where the environment is variable."

Brown et al. Model

- What did they find?

Brown et al. Model

Case 1.1
- No aesthetic quality differences
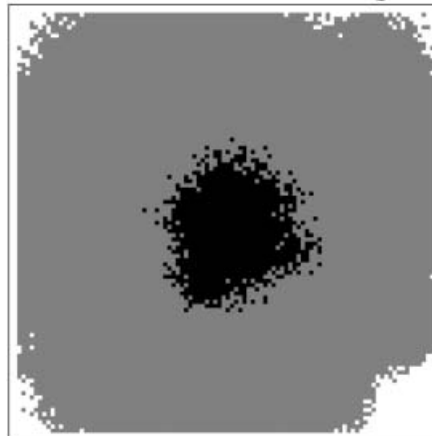- No density preference
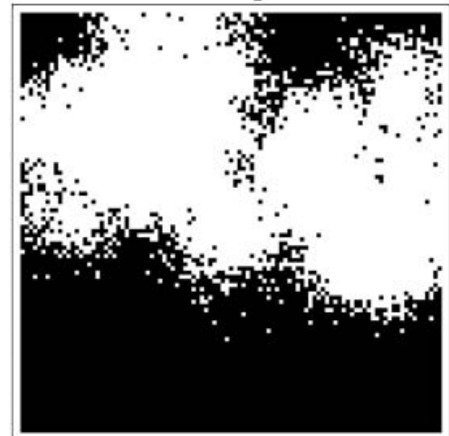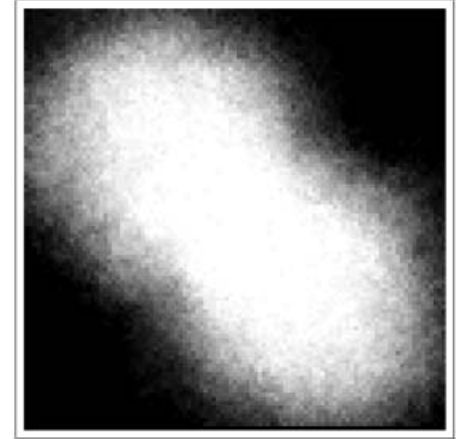- Weak closeness to facilities preference

Brown et al. Model

Case 1.3
- Aesthetic quality peaks
- Strong density preference
- Weak closeness to facilities preference
- Weak aesthetic quality preference

A. Single Realization
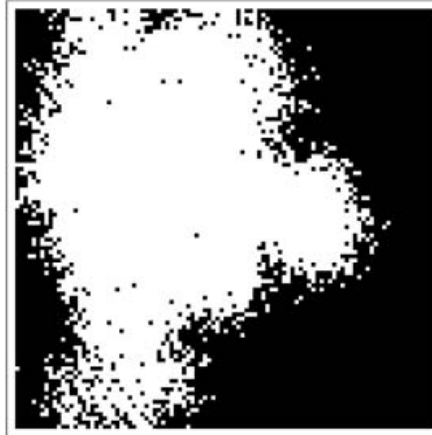
B. Frequency Developed
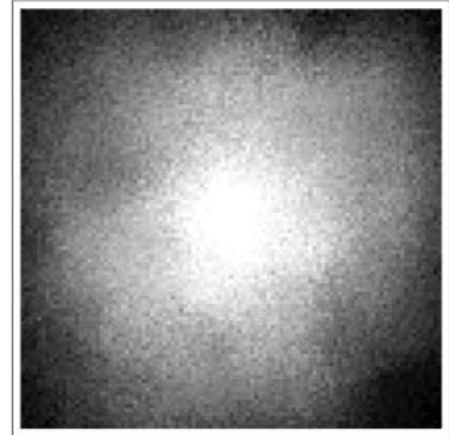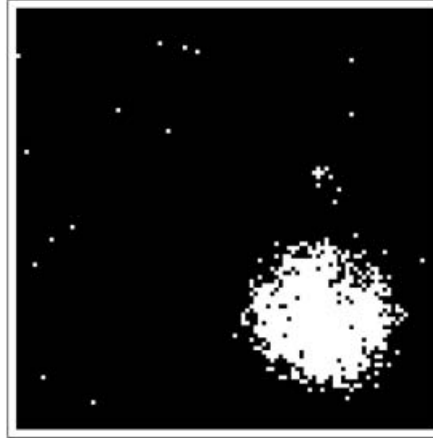
C. Variant/Invariant Region
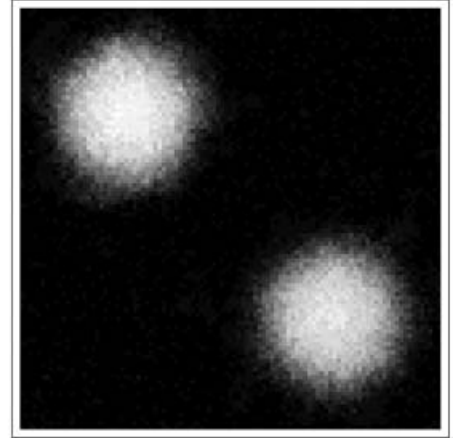
D. Reference Map

Brown et al. Model

Case 2.1
- Aesthetic quality peaks
- Strong density preference
- Weak closeness to facilities preference
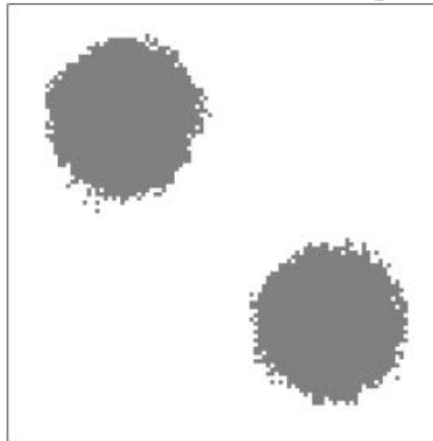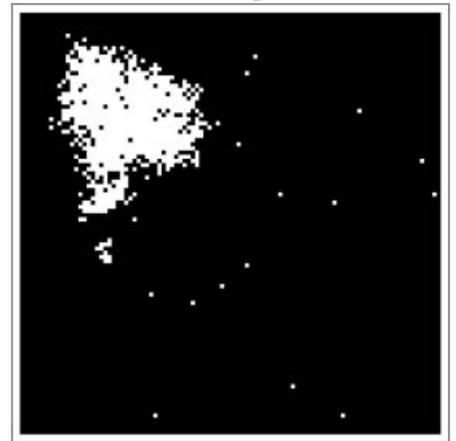- Strong aesthetic quality preference

A. Single Realization

B. Frequency Developed

C. Variant/Invariant Region

D. Reference Map

Hypothesis 1

- "Our first hypothesis was that a model (and a system) with more and stronger feedbacks would be more path dependent than a model with fewer and/ or weaker feedbacks"

- NetLogo results:

Hypothesis 2

- "Our second hypothesis was that where the environment is relatively homogenous, land-use histories would be more path dependent than where the environment is variable."

- NetLogo results:

Brown et al. Model

- Washtenaw County, MI Model
- Implications for policy?
  - Desired outcomes
- Prediction results?
- Overfitting?
- Abstractions/Simplifications?
- What would you add?
- Take home from model?