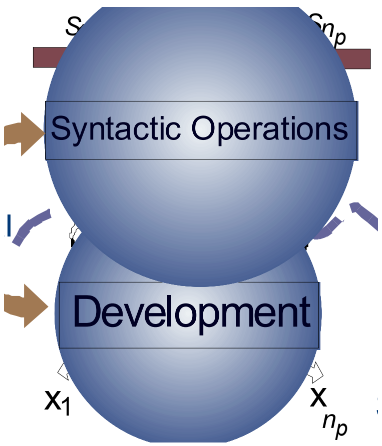

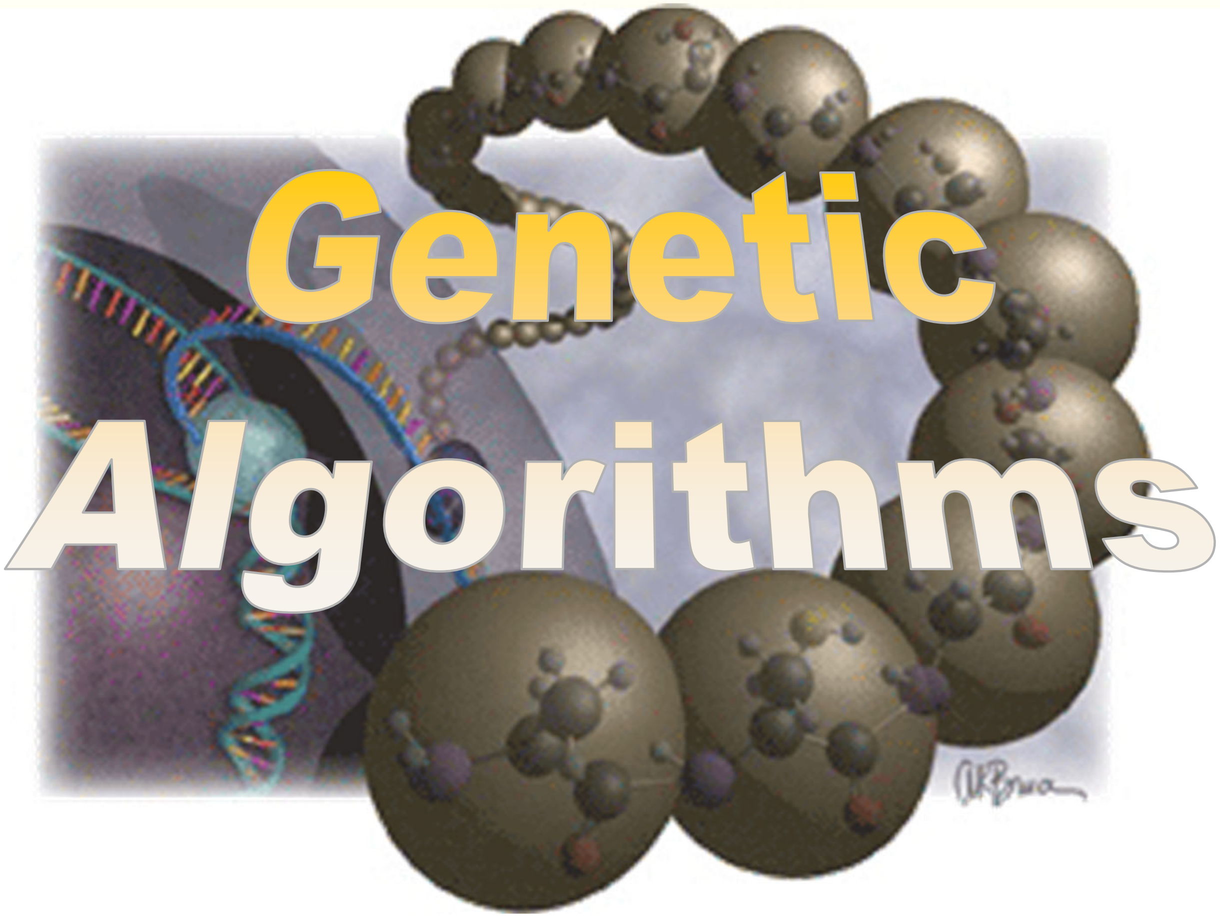

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key events coming up

- Labs: 35% (ISE-483)
  - Complete 5 (best 4 graded) assignments based on algorithms presented in class
    - Lab 4 : April 8th
      - Evolutionary Algorithms, (Assignment 4)
        - Delivered by SSIE583 Group 2
        - Due April 15th
    - Lab 5: April 29th
      - Ant Clustering Algorithm, (Assignment 5)
        - Delivered by Group 1
        - Due May 6th
- 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
  - April 25th or April 29th
    - Conrad, M. [1990]. "The geometry of evolution.“ *Biosystems* **24**: 61-81.
      - Mario Franco
    - Stanley, Kenneth O., Jeff Clune, Joel Lehman, and Risto Miikkulainen. “Designing Neural Networks through Neuroevolution.” *Nature Machine Intelligence* **1**, no. 1 (January 2019): 24–35.
      - Jessica Lasebikan
    - Lindgren, K. [1991]."Evolutionary Phenomena in Simple Dynamics." In: *Artificial Life II*. Langton et al (Eds). Addison-wesley, pp. 295-312.
      - Akshay Gangadhar
    - Salahshour, Mohammad. “Interaction between Games Give Rise to the Evolution of Moral Norms of Cooperation.” *PLOS Computational Biology* **18**, no. 9 (September 29, 2022): e1010429
      - Srikanth Iyer
    - Discussion by all

bit.ly/atBIC

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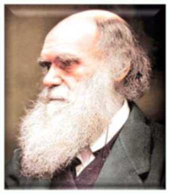
until now

- Class Book
  - Floreano, D. and C. Mattiussi [2008]. *Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies*. MIT Press. Preface**, Chapters 1 and 4.**
- Lecture notes
  - Chapter 1: What is Life?
  - Chapter 2: The logical Mechanisms of Life
  - Chapter 3: Formalizing and Modeling the World
  - Chapter 4: Self-Organization and Emergent Complex Behavior
  - Chapter 5: Reality is Stranger than Fiction
  - Chapter 6: Von Neumann and Natural Selection
    - posted online @ http://informatics.indiana.edu/rocha/i-bic



- Papers and other materials
  - Optional
    - Nunes de Castro, Leandro [2006]. *Fundamentals of Natural Computing: Basic Concepts, Algorithms, and Applications*. Chapman & Hall.
      - Chapter 2, 7, 8
      - **Chapter 3, sections 3.1 to 3.5**

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- Projects
  - Due by **May 8th** in Brightspace, “Final Project Paper” assignment
    - ALIFE 2023
      - Not to submit to actual conference due date (April 3rd , 2024)
      - https://2024.alife.org/
      - 8 pages, author guidelines:
      - https://2024.alife.org/call_paper.html
      - MS Word and Latex/Overleaf templates
    - Preliminary ideas **by March 15**
      - Submit to “Project Idea” assignment in Brightspace.
  - Individual or group
    - With very definite tasks assigned per member of group

ALIFE 2024

Tackle a real problem using bio-inspired algorithms, such as those used in the labs.

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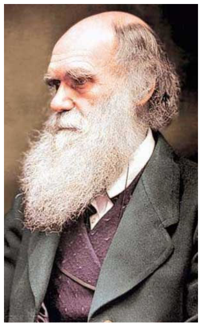
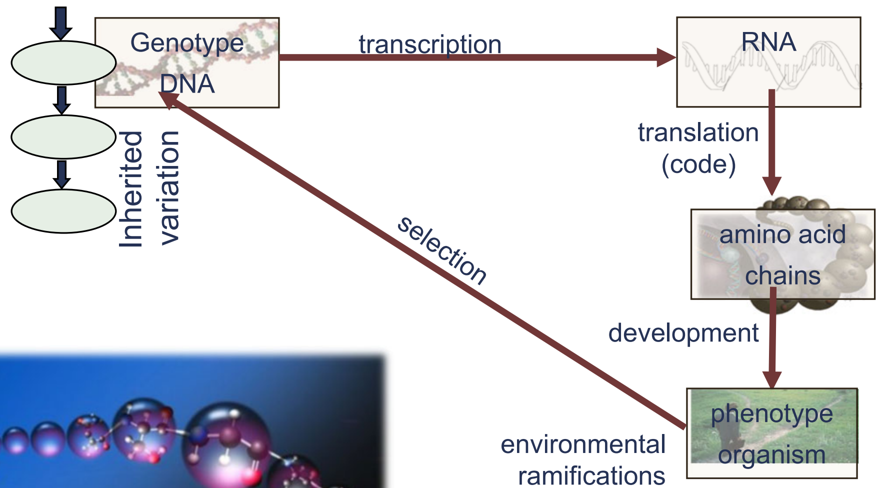
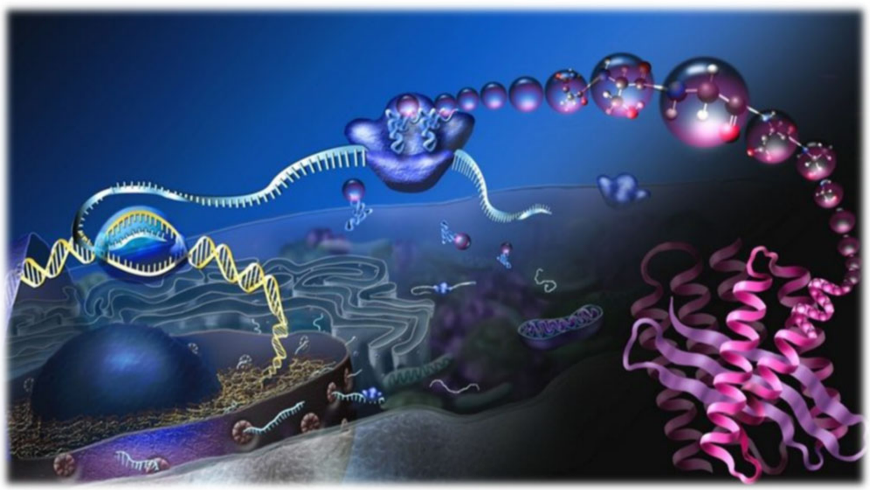
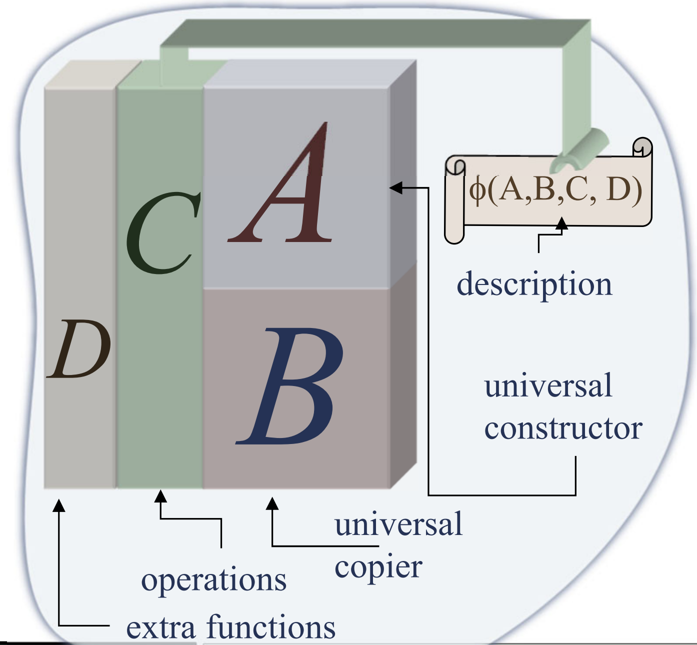
from cybernetic mechanisms to bio-inspired algorithms









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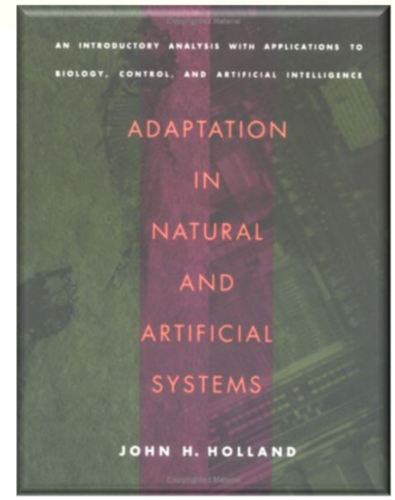
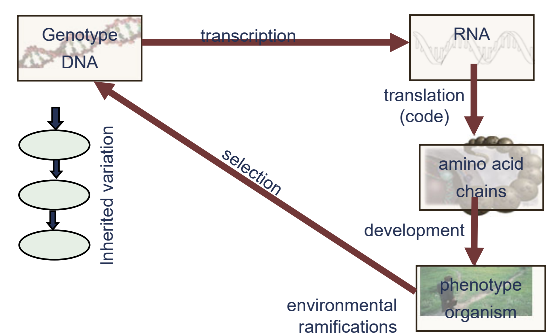
History of evolutionary computation

- Evolutionary Operation
  - Box (1957)
    - Perturbations to continuous variables followed by selection to improve industrial productivity
- Evolution Strategies
  - Rechenberg (1960's), Schweffel (1970's)
    - To optimize real-valued parameters in wind-tunnel experiments
    - Real-valued genotypes under variation and selection
- Evolutionary Programming
  - Fogel, Owens, and Walsh (1966)
    - Evolution of tables of state-transition functions (diagrams) under mutation and selection
- Artificial ecosystems
  - Conrad and Pattee (1970)
    - Population of artificial cells evolving with genotype and phenotype
- Other early evolution-inspired algorithms and models
  - Barricelli CA-like model(1957), game-strategy model (1963)
    - Symbiogenetic evolution
  - Friedman (1957, 1959), Bledsoe (1961), Bremmermann (1962)
- Genetic Algorithms
  - John Holland (1960's and 1970's)
    - *Adaptation in Natural and Artificial Systems*, University of Michigan Press, 1975. (MIT Press, second edition 1992)





via genetic algorithms

- Search algorithms based on the mechanics of Natural Selection
  - Holland, Conrad, Fogel
  - Based on distinction between a machine and a description of a machine
    - Solution alternatives for optimization problems

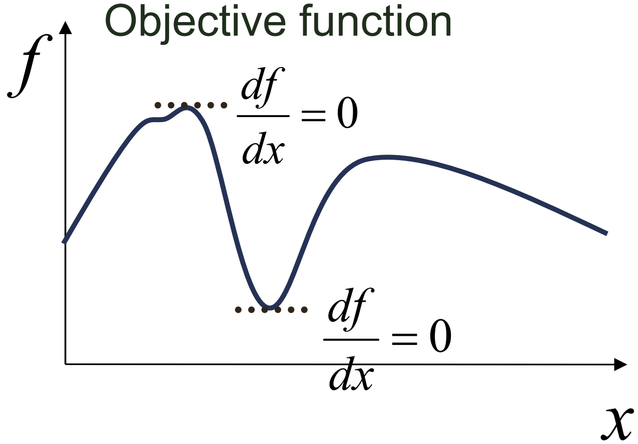
Direct analysis depends on

Knowing the function

Existence of derivatives

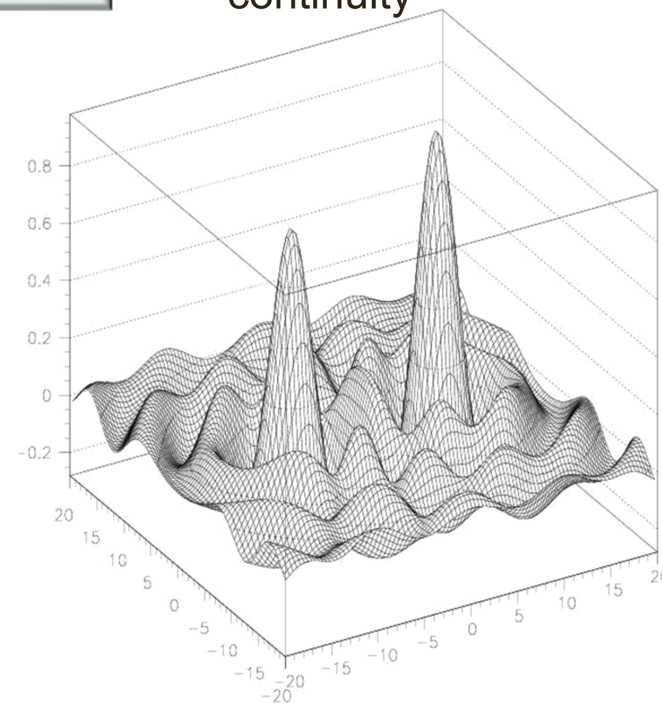
continuity

Objective function



"hill-climbing"

"hop" on the function and move along the steepest direction until a local extrema is found



Random Search

directionless

Enumerative Search

Search point by point

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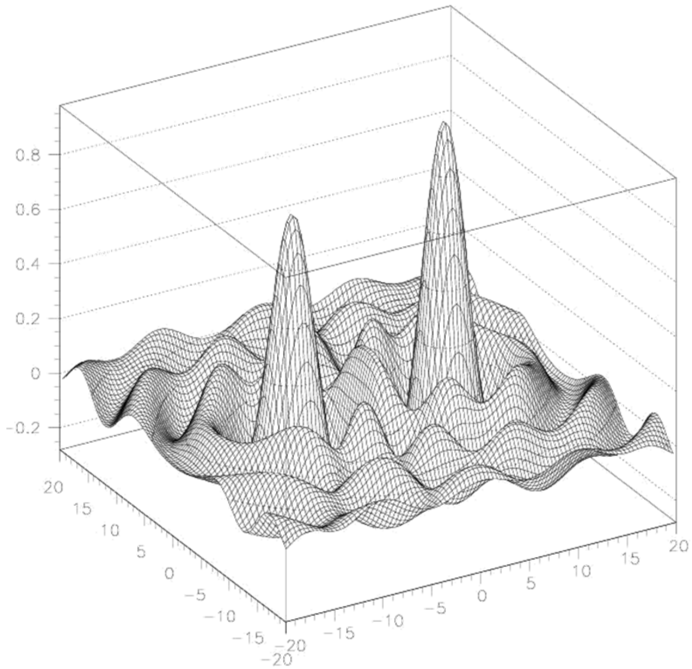
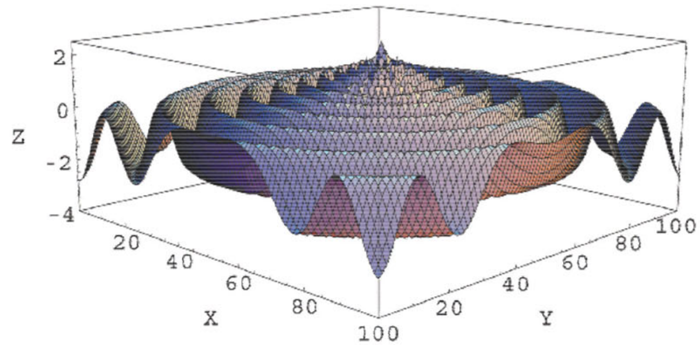
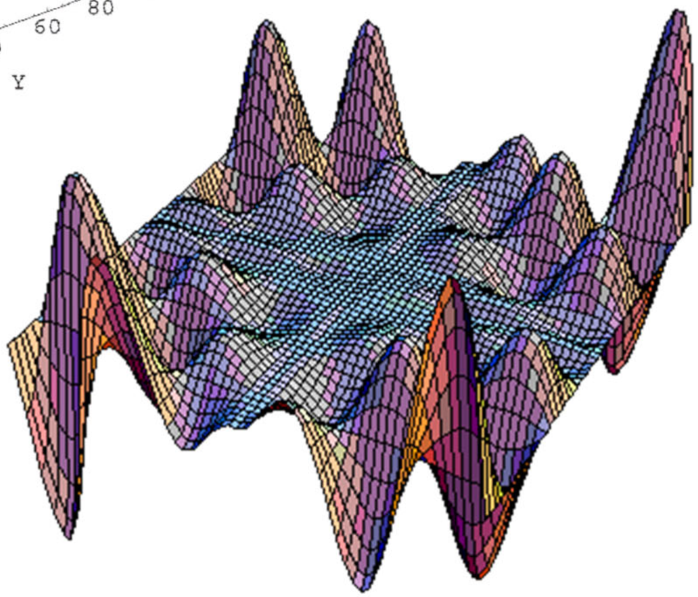
examples







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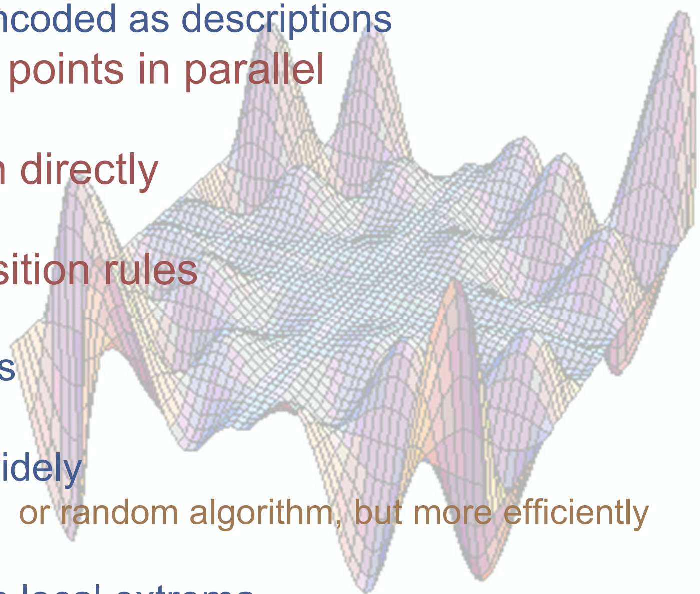
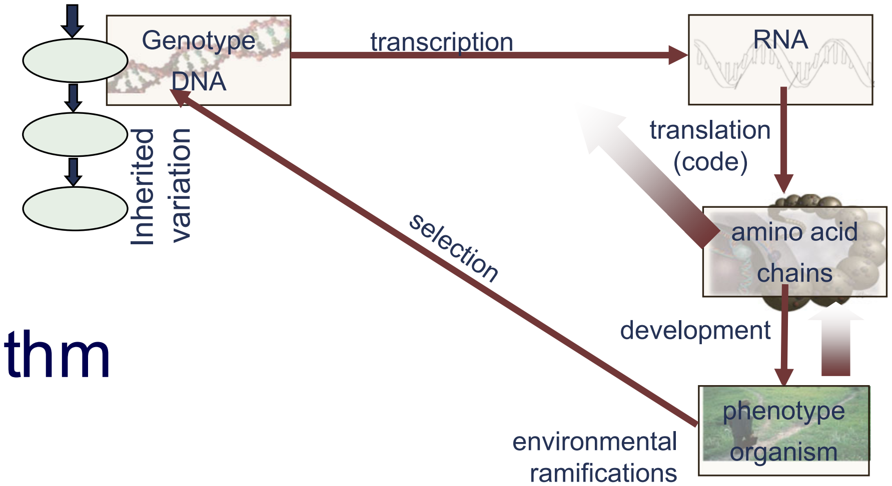
- Work with an encoding of the parameter set, not the parameters themselves
  - solution alternative encoded as descriptions
- Search a population of points in parallel
  - Not a single point
- Uses objective function directly
  - Not derivatives
- Uses probabilistic transition rules
  - Statistical bias
  - Not deterministic rules
- Advantages
  - Samples the space widely
    - like an enumerative or random algorithm, but more efficiently
    - Directed search
  - Not so easily stuck on local extrema
    - Population search
    - Variation mechanisms to search new points

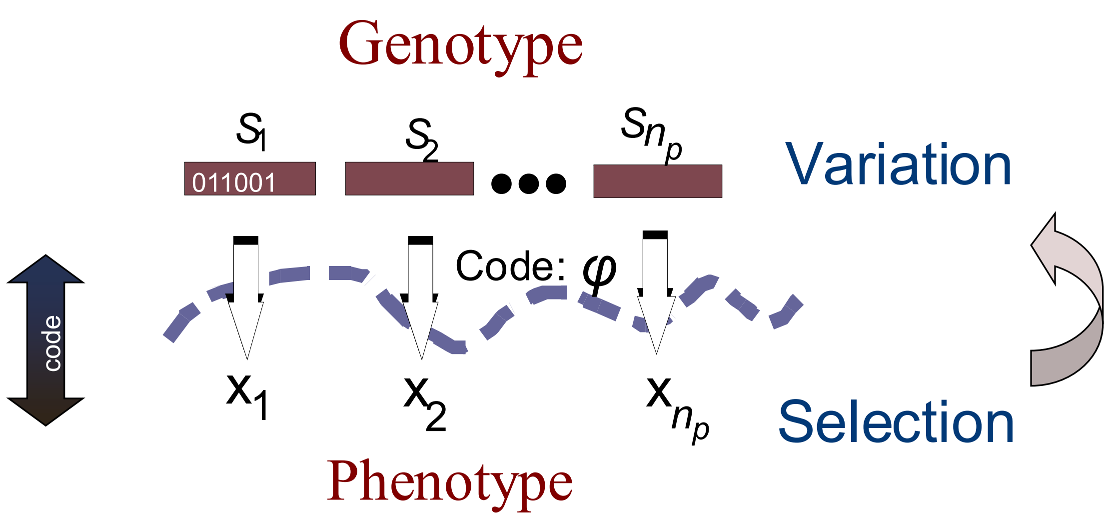


artificial genotype/phenotype mapping

- Search algorithms based on the mechanics of Natural Selection
  - Based on distinction between a machine and a description of a machine
  - Solution alternatives for optimization problems



Traditional Genetic Algorithm



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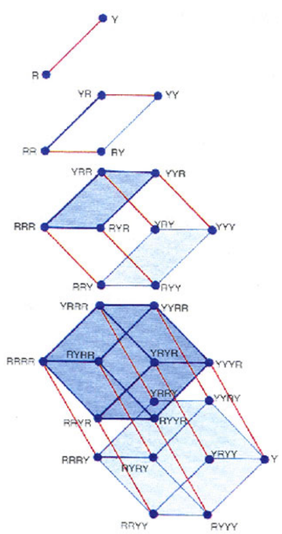
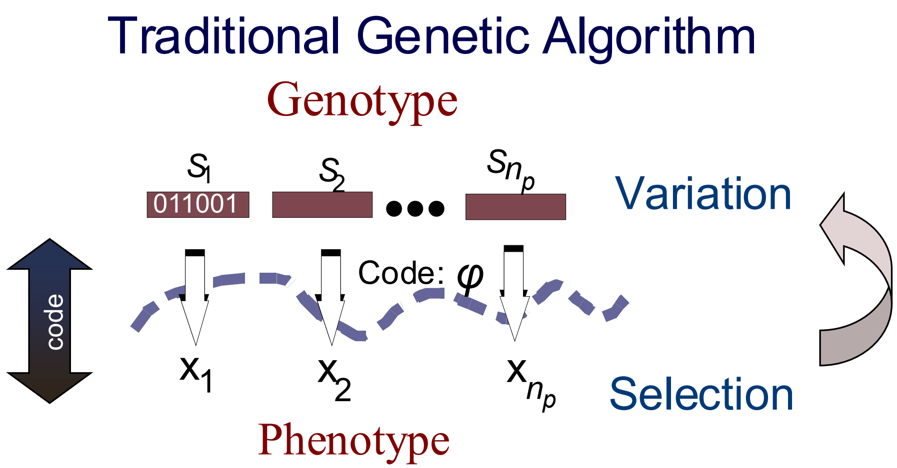
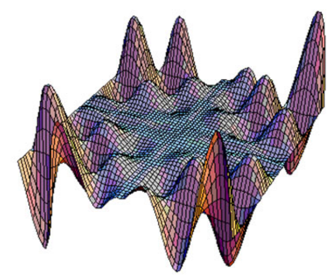
in genetic algorithms

- Solution space encoded as finite-length string over a finite alphabet
  - E.g. {0, 1}
- GA's exploit coding similarities
  - Searches the code space, not the solution space







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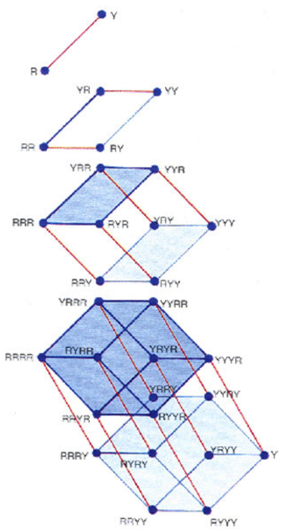
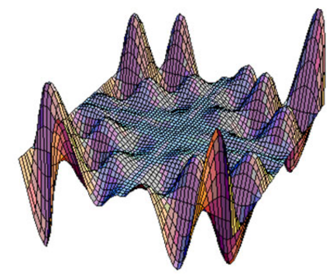
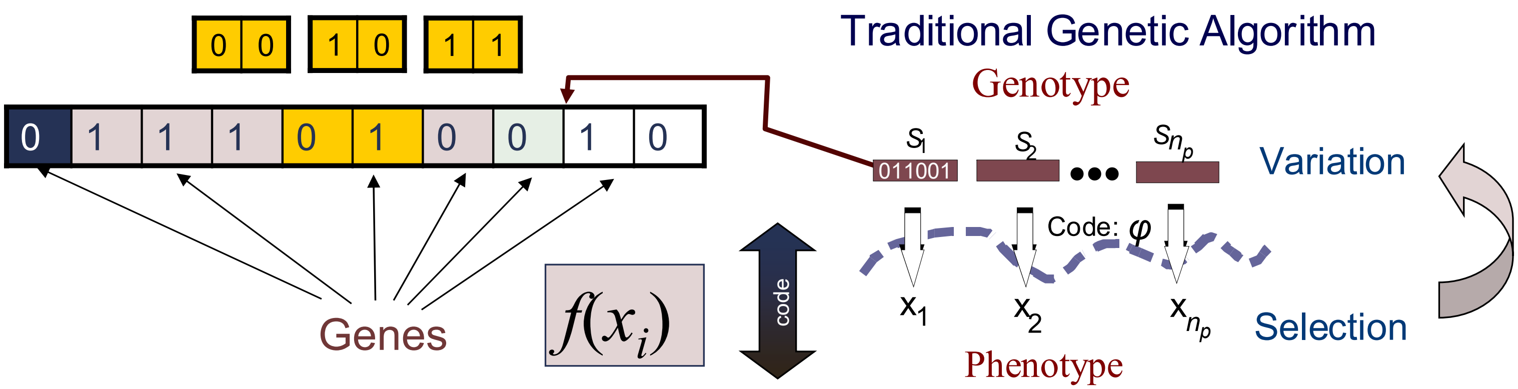
The workings

1) Generate Random population of bit-strings
   - Chromosomes/Genotypes
     - A candidate solution to a problem
   - Genes
     - Single or short blocks of adjacent bits
   - Allele
     - Actual value of a gene
2) Evaluate Fitness Function for each decoded solution
3) Reproduce next generation
   - Genotypes of solutions with higher fitness value reproduce with higher probability
4) Go back to 2)

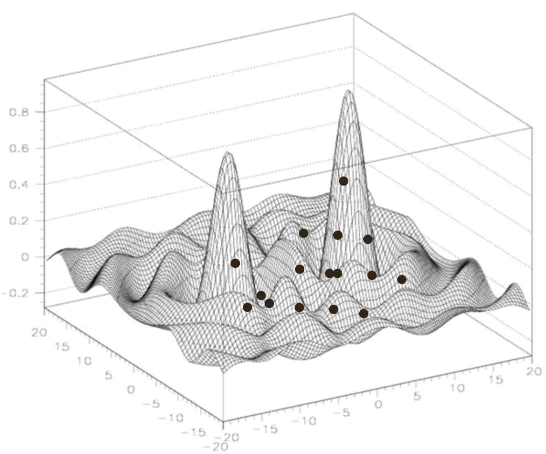


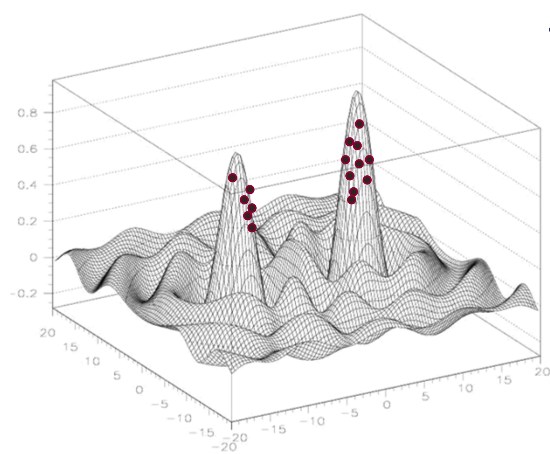




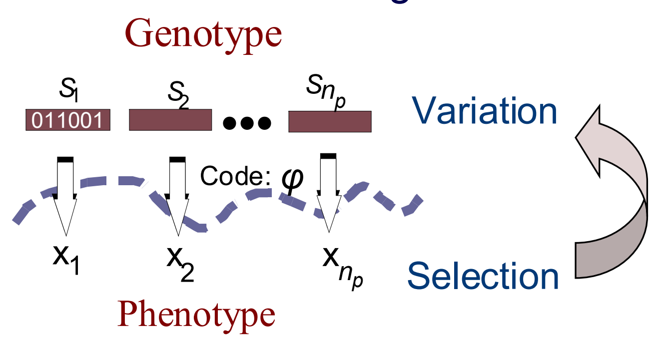
biased population generation

- Solution space encoded as finite-length string over a finite alphabet
  - E.g. {0, 1}
- GA's exploit coding similarities
  - Searches the code space, not the solution space
- Searches the space with many alternatives in parallel
  - Avoids getting trapped in local optima
  - Higher probability of finding better solutions
- Not random search
  - Search towards regions with likely improvement
  - Better solutions reproduce more often
    - Does not work in very rugged, chaotic, uncorrelated landscapes



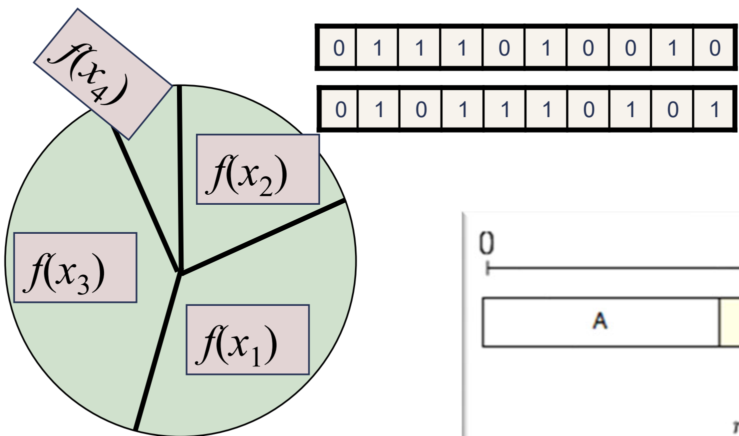


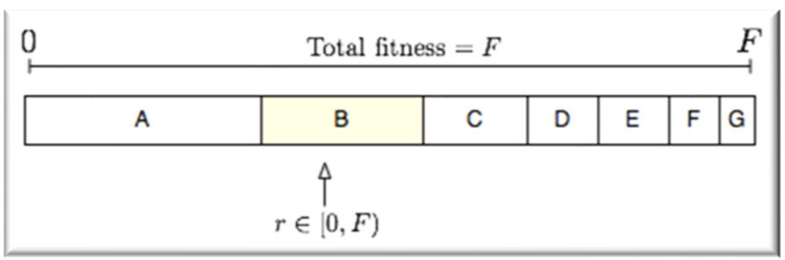
Traditional Genetic Algorithm

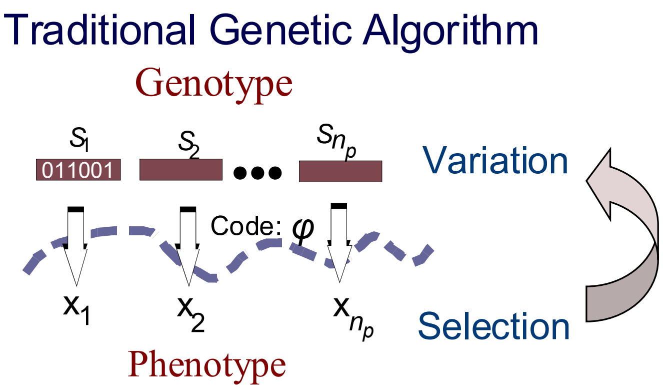


Modeling fitness selection

1) Reproduction: New population is generated
   a) Selection
      - Select two parent chromosomes from a population according to their fitness
         - Biased roulette wheel according to fitness of solution
         - Elite group
         - Tournament

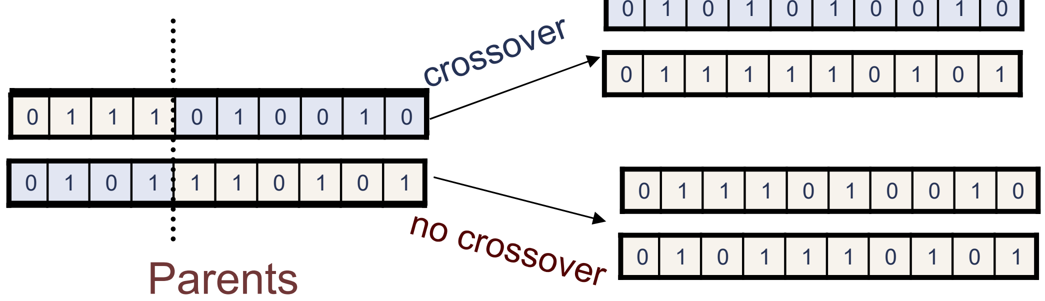






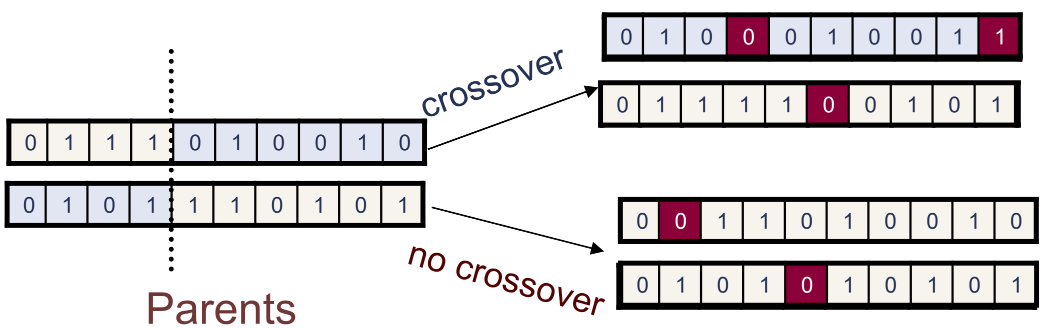
Variation: crossover

1) Reproduction: New population is generated
   a) Selection
      - Select two parent chromosomes from a population according to their fitness
   b) Variation: Crossover
      - With a ***crossover probability*** produce offspring pair by recombining parents.



Variation: mutation

1) Reproduction: New population is generated
   a) Selection
      - Select two parent chromosomes from a population according to their fitness
   b) Variation: Crossover
      - With a ***crossover probability*** produce offspring pair by recombining parents.
   c) Variation: Mutation
      - With a ***mutation probability*** mutate (bit flip) new offspring at each bit position



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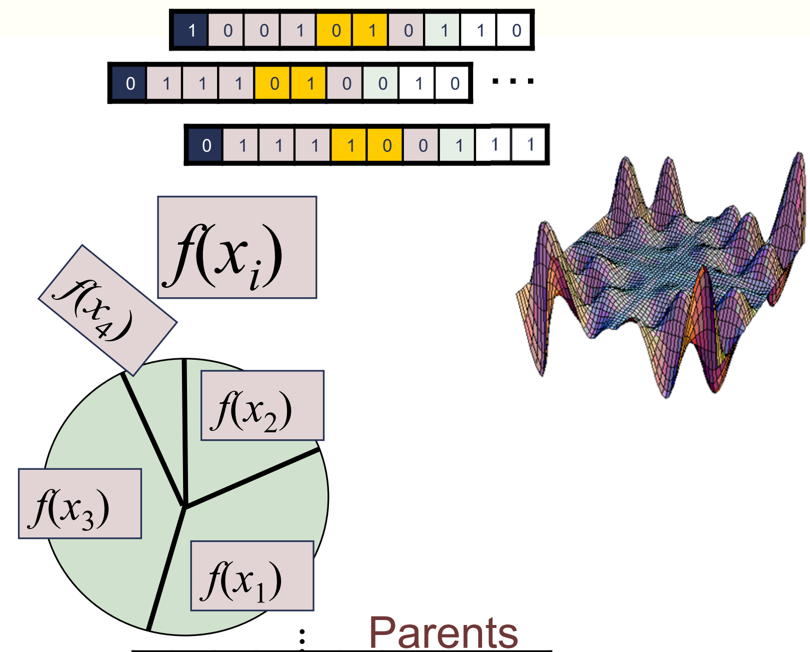
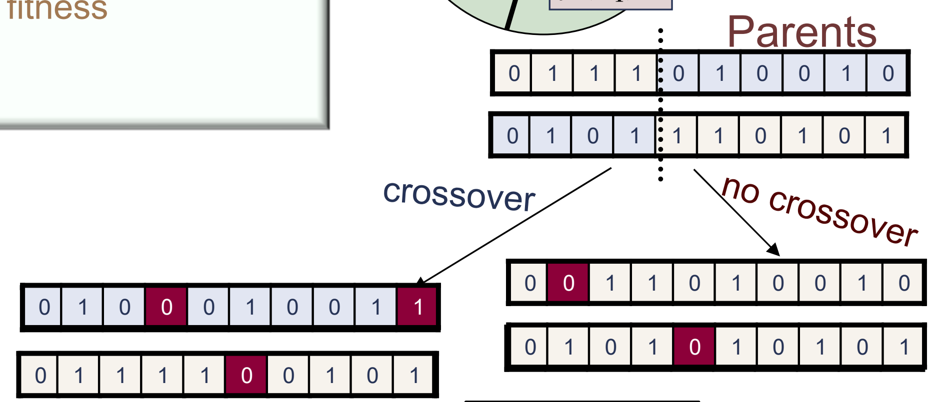
The workings

1) Generate Random population of bit-strings
2) Evaluate Fitness Function for each decoded solution
3) Reproduce next generation
   - Selection by fitness
   - Variation
     - crossover and mutation
   - Fill new population
4) Go back to 2) until stop criteria is met
   - Desired fitness
   - Specified number of generations
   - Convergence
     - Lack of variability in population and/or fitness
       - Tends to a peak





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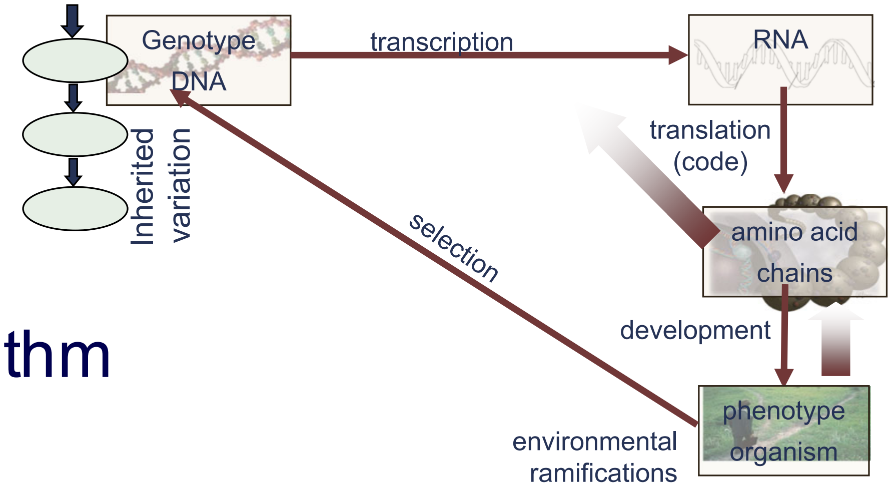

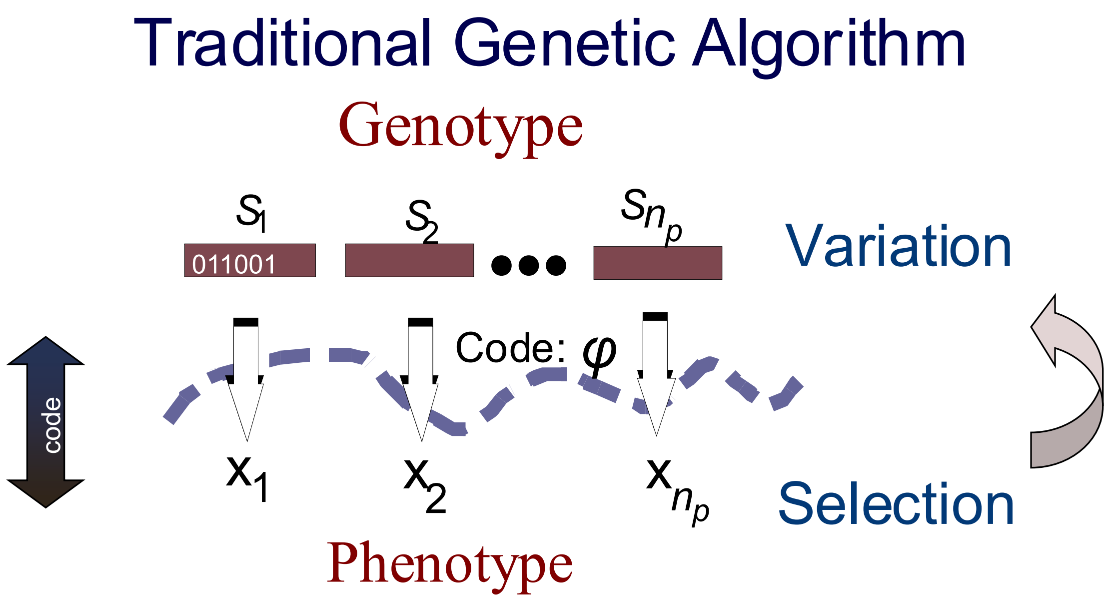

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readings

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    - **Chapter 7**
- Lecture notes
  - Chapter 1: What is Life?
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      - Chapter 5, 7.7, 8.3.1, 8.3.6,