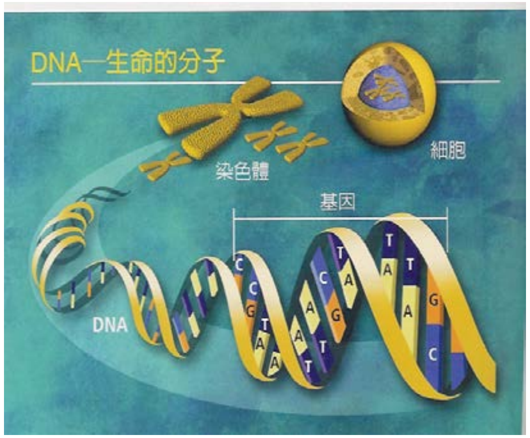


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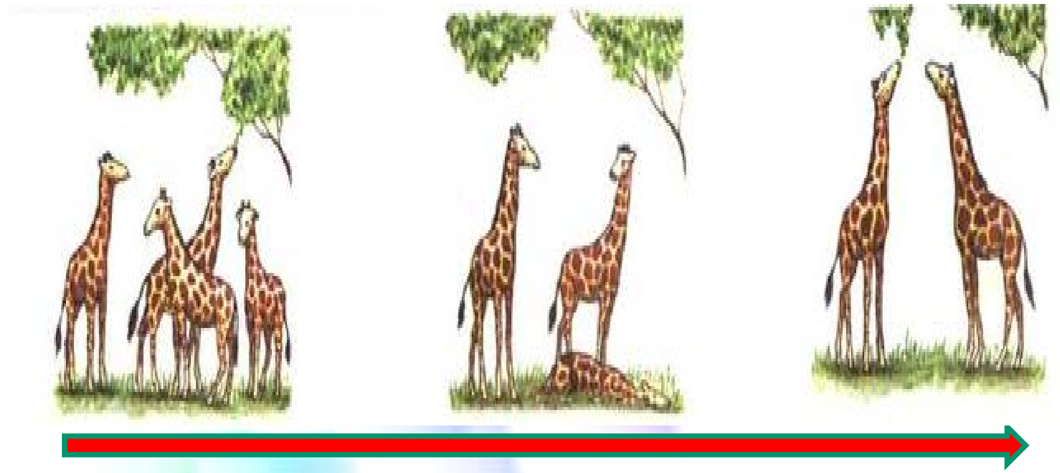

# Genetic Algorithms
# 遺傳基因演繹法

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# Class Contents

- Soft Computing
- Evolution Computing (EC)
  - Part 0. INTRODUCTION
  - Part I. GENETIC ALGORITHMS
  - Part II. NUMERICAL OPTIMIZATION
  - Part III. EVOLUTION PROGRAMS

# Contents

# Part 0. INTRODUCTION

I. Nature Inspired Algorithmic Techniques

II. Natural Genetics

III. Evolutionary Computation

# I. Nature Inspired Algorithmic Techniques

# Motivations for EPs: 1

- Nature has always served as a source of inspiration for engineers and scientists
- The best problem solver known in nature is:
  - the (human) brain that created “the wheel, New York, wars and so on” (after Douglas Adams’ Hitch-Hikers Guide) → neurocomputing
  - the evolution mechanism that created the human brain (after Darwin’s Origin of Species) → evolutionary computing

# Motivations for EPs : 2

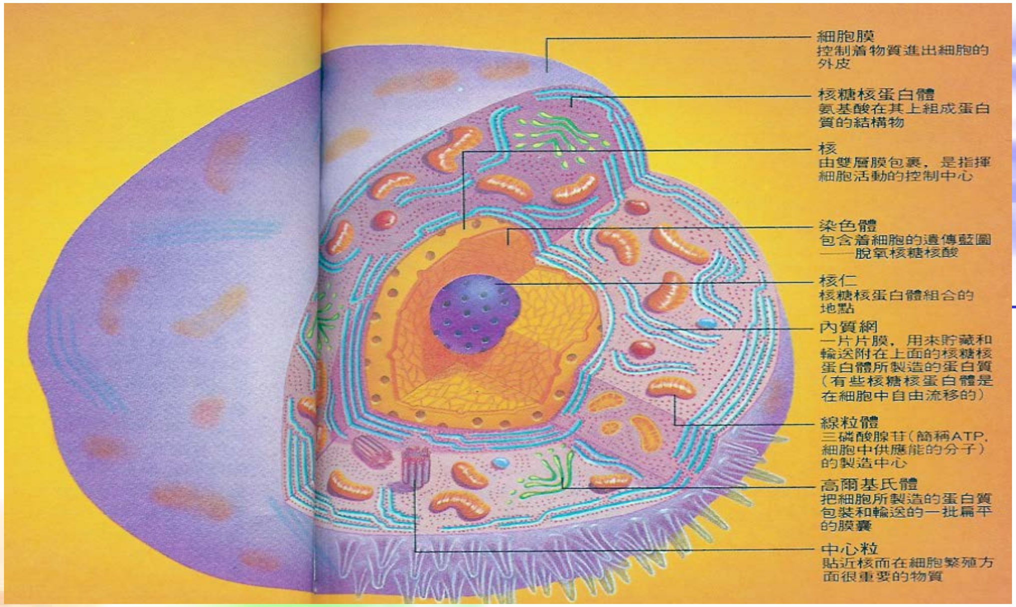
- Developing, analyzing, applying problem solving methods a.k.a. algorithms is a central theme in mathematics and computer science
- Time for thorough problem analysis decreases
- Complexity of problems to be solved increases

Consequence:

Robust problem solving technology needed

# II. Natural Genetics

# Cell



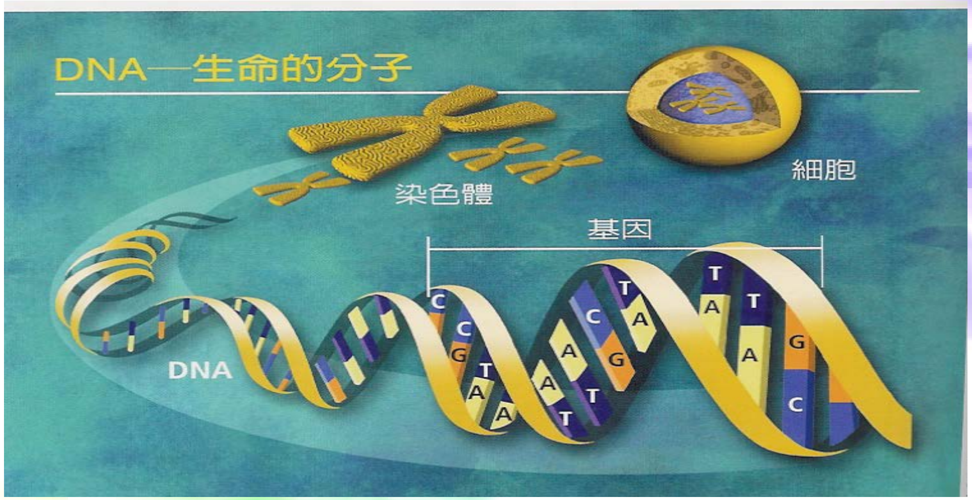

Cell:
Nucleus, Cytoplasm, and Cell Membrane

Chromosome:
DNA molecule

DNA (Deoxyribo Nucleic Acid 脫氧核糖核酸):
A(腺嘌呤), T(胸腺嘧啶), G(鳥糞嘌呤), C(胞嘧啶)

Gene:
-A-T-G-C-T-A-C-G-T-D-A-C-T-A

# DNA and Genes




- DNA is a large molecule made up of fragments. There are several fragment types, each one acting like a letter in a long coded message:

  -A-T-G-C-T-A-C-G-T-D-A-C-T-A-

- Certain groups of letters are meaningful together these groups are called genes

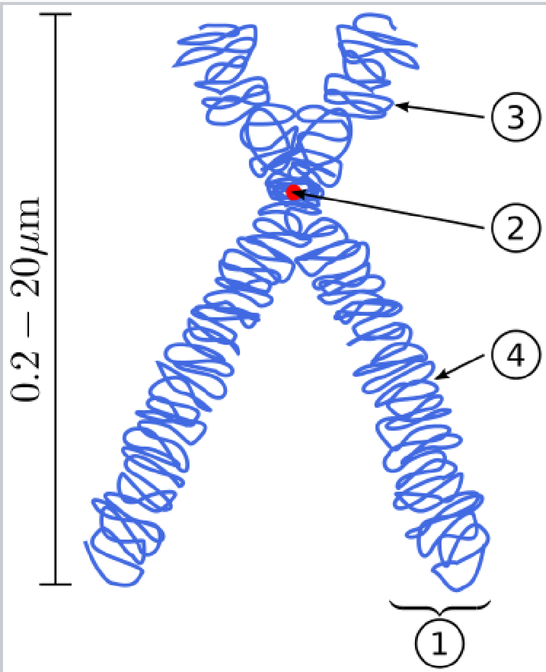
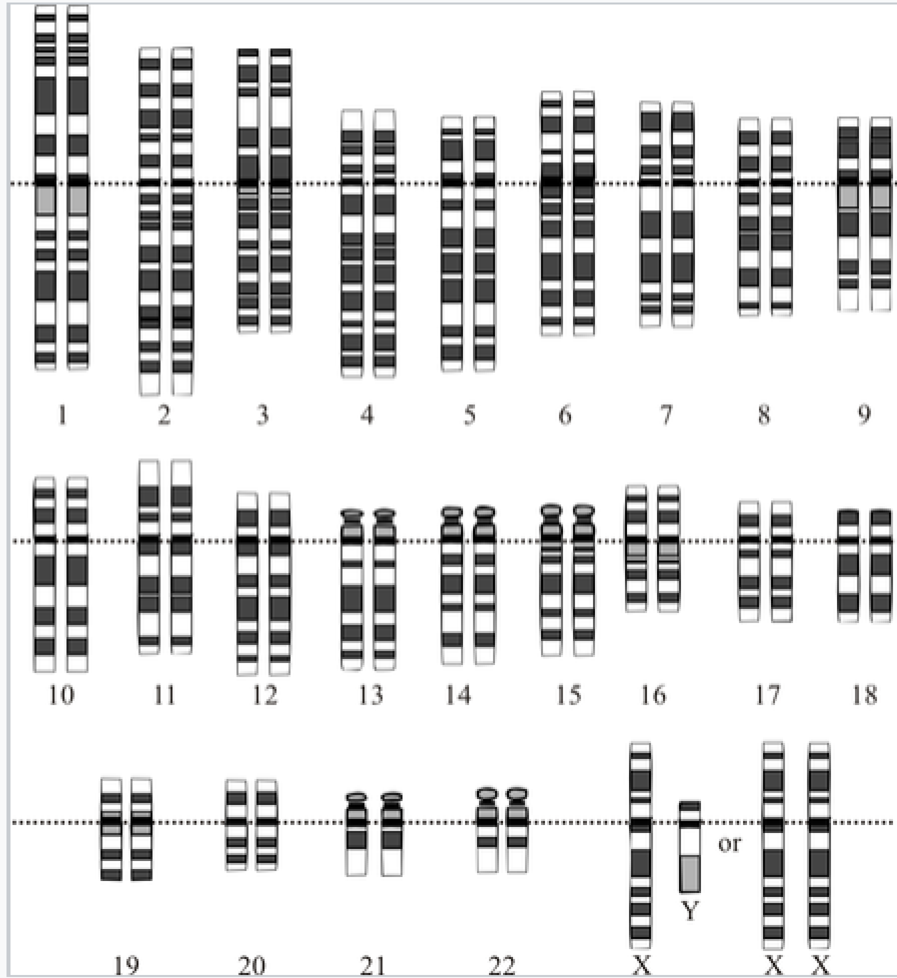



Diagram of a replicated and condensed metaphase eukaryotic chromosome. (1) Chromatid – one of the two identical parts of the chromosome after S phase. (2) Centromere – the point where the two chromatids touch. (3) Short (p) arm. (4) Long (q) arm.

一對染色體



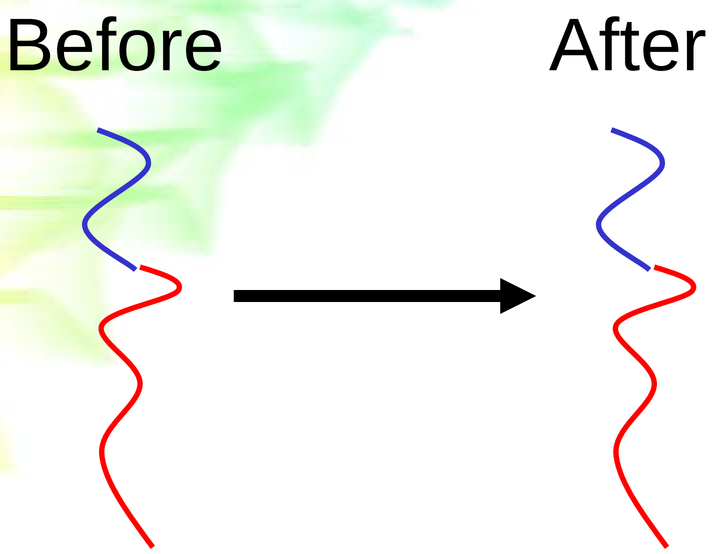

根據一般人類體細胞所擁有的染色體而繪製的「染色體組型圖」。

# Genotype vs. Phenotype

- Genotype (DNA inside) determines phenotype
- A central claim in molecular genetics: only one way flow
  - Genotype $\longrightarrow$ Phenotype
  - Genotype $\not\longleftarrow$ Phenotype

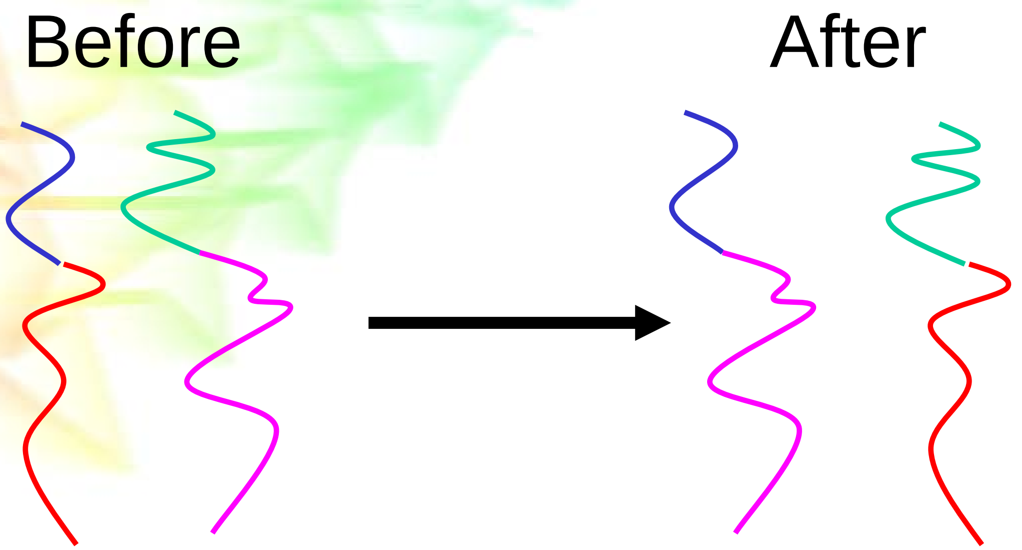
# Reproduction

- Reproductive cells are formed by one cell splitting into two.



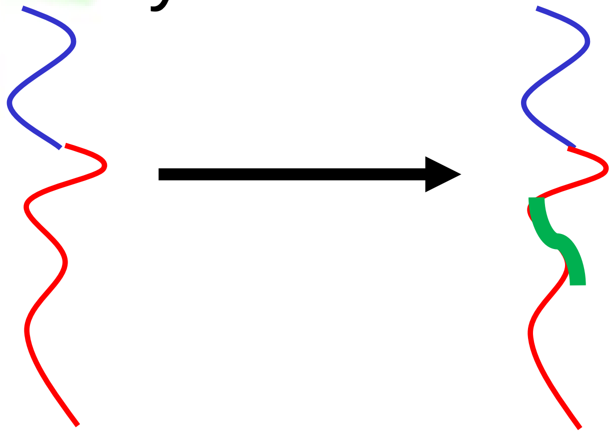
# Recombination

During crossover the chromosome link up and swap parts of themselves:



# Mutation

- Occasionally some of the genetic material changes very slightly during this process
- This means that the child might have genetic material information not inherited from either parent
- This is most likely to be catastrophic



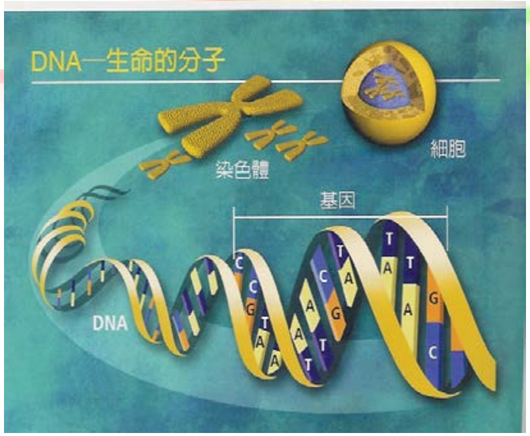
# Theory of Evolution

- From time to time, reproduction, crossover and mutation produce new genetic material or new combinations of genes
- "Good" sets of genes get reproduced more
- "Bad" sets of genes get reproduce less
- Evolutionists claim that all the species of plants and animals have been produced by this slow changing of genetic material - with organisms becoming better and better at surviving in their niche, and new organisms evolving to fill any vacant niche.

# Evolution as Search

- We can think of evolution as a search through the enormous genetic parameter space for the genetic make-up that best allows an organism to reproduce in its changing environment.
- Since it seems pretty good at doing this job, we can borrow ideas from nature to help us solve problems that have an equally large search spaces or similarly changing environment.

# III. Evolutionary Computing (EC)

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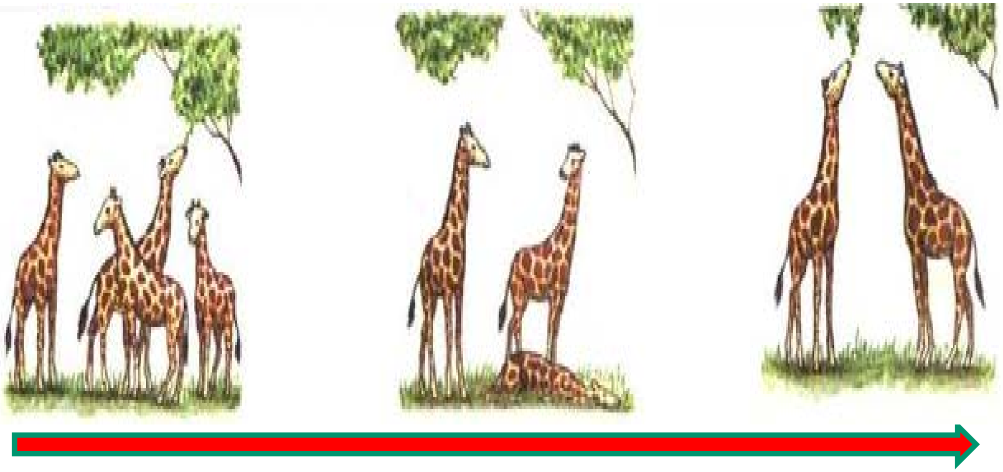


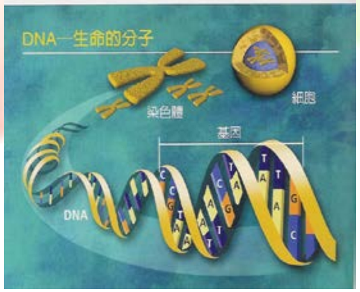
# Introduction

- The Evolutionary Mechanism
- History
- Advantage & Disadvantage
- Domains of Application
- Sources of Information
- Summary

# The Evolution Mechanism

- Evolutionary Computing(EC) / Evolutionary Computation(EC) /Evolutionary Algorithms(EAs)/Evolution Programs(EPs)

  - The principle of *hereditary* and *evolution*
  - A population of possible *solutions*

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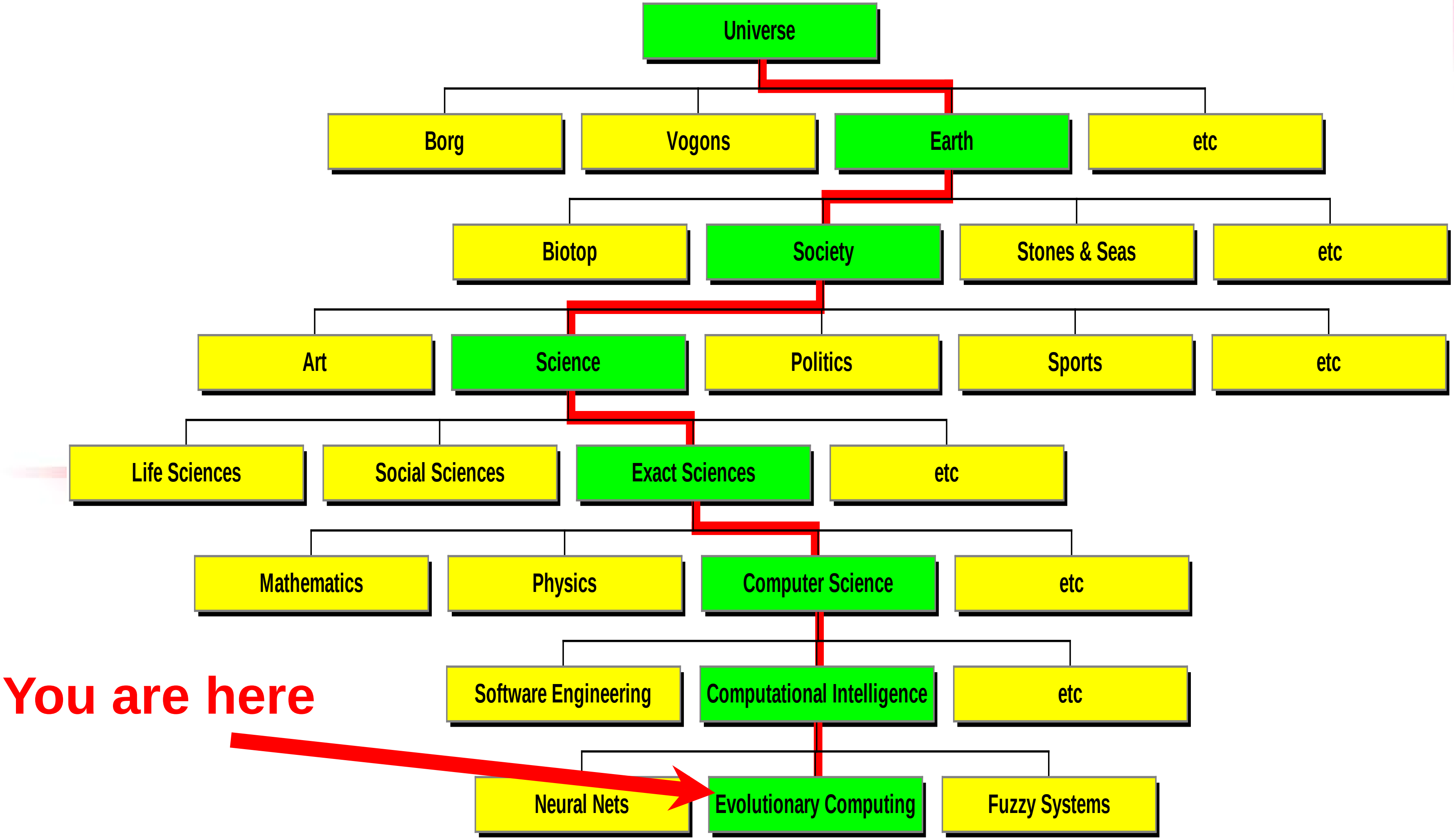
# The Main Evolutionary Computing Metaphor

| EVOLUTION | | PROBLEM SOLVING |
|---|---|---|
| Environment | ⟷ | Problem、Constraint |
| Individual | ⟷ | Candidate Solution |
| Fitness | ⟷ | Quality |

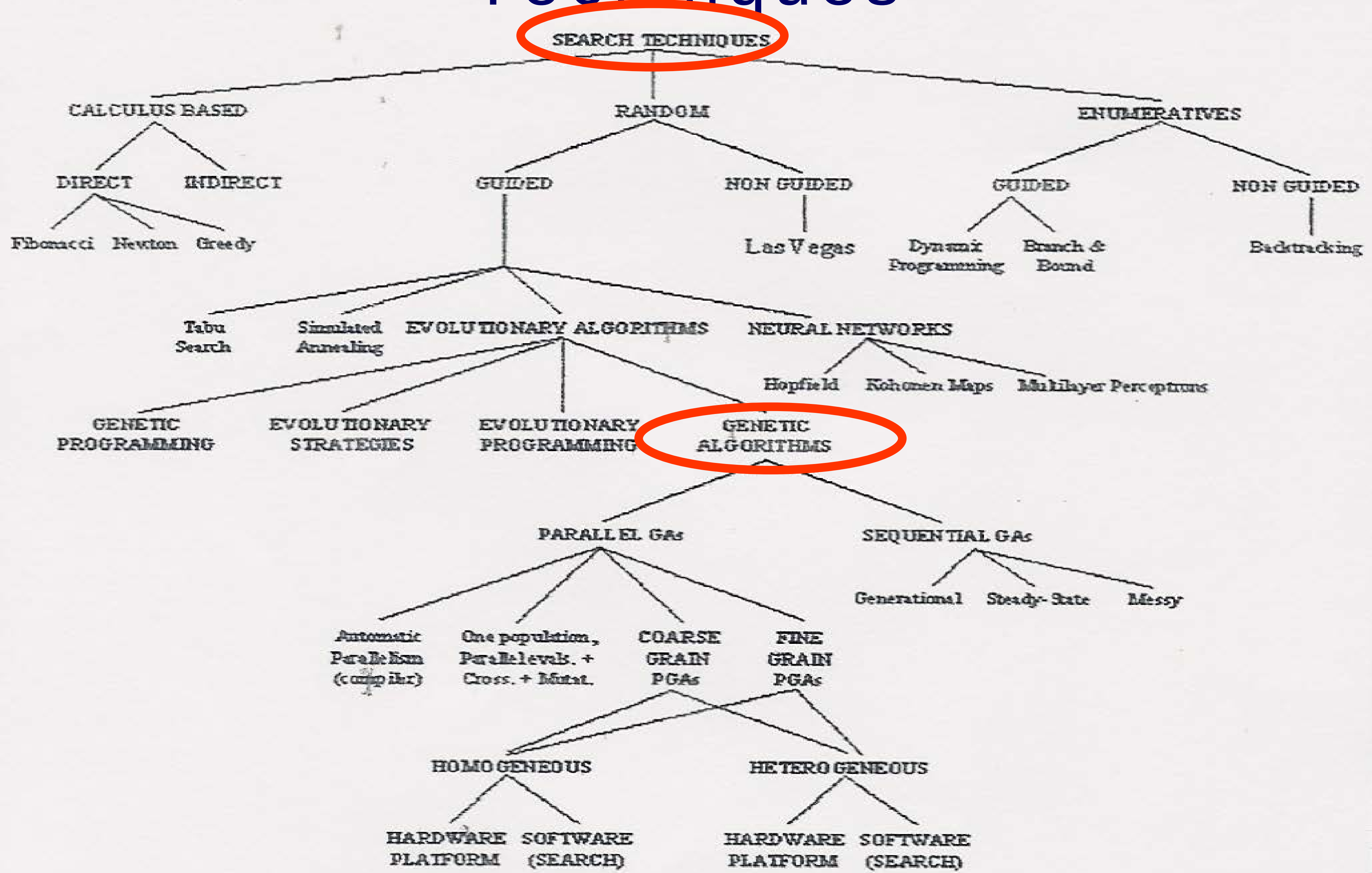
# Positioning of EC



# Positioning of EC

- EC is part of computer science
- EC is not part of life sciences/biology
- Biology delivered inspiration and terminology
- EC can be applied in biological research

# Classification of Search Techniques



# The Technique Views of EPs

- As a method to *simulate biological systems*
- As an approach for *machine learning*
- An approach to *computational intelligence* and for *soft computing*
- As a *search* paradigm
- As generators for new ideas and for computer art

# History

| Year | Inventor | Technique | Individual |
|---|---|---|---|
| 1958 | Friedberg | learning machine | virtual assembler |
| 1959 | Samuel | mathematics | polynomial |
| 1965 | Fogel, Owens and Walsh | evolutionary programming | automaton |
| 1965 | Rechenberg, Schwefel | evolutionary strategies | real-numbered vector |
| 1975 | Holland | genetic algorithms | fixed-size bit string |
| 1978 | Holland and Reitmann | genetic classifier systems | rules |
| 1980 | Smith | early genetic programming | var-size bit string |
| 1985 | Cramer | early genetic programming | tree |
| 1986 | Hicklin | early genetic programming | LISP |
| 1987 | Fujiki and Dickinson | early genetic programming | LISP |
| 1987 | Dickmanns, Schmidhuber and Winklhofer | early genetic programming | assembler |
| 1992 | Koza | genetic programming | tree |

# Brief History

- 1948, Turing:
  proposes "genetical or evolutionary search"
- 1962, Bremermann
  optimization through evolution and recombination
- 1960, L. Fogel, Owens and Walsh
  introduce evolutionary programming **(EP)**
- 1965, Rechenberg
  introduces evolution strategies **(ES)**
- 1975, Holland
  introduces genetic algorithms **(GAs)**
- 1992, Koza
  introduces genetic programming **(GP)**

# The Rise of EPs

- 1985: first international conference (ICGA)
- 1990: first international conference in Europe (PPSN)
- 1993: first scientific EC journal (MIT Press)
- 1997: launch of European EC Research Network EvoNet

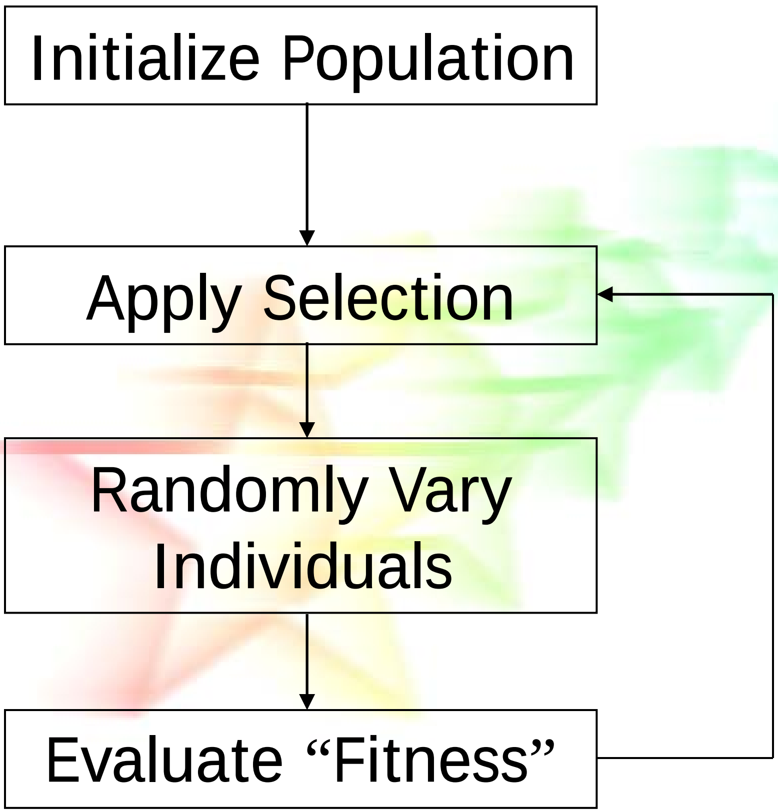
# EPs in the early 21$^{st}$ Century

- 3 major EC conferences, about 10 small related ones
- 3 scientific core EC journals
- 750-1000 papers published in 2003 (estimate)
- EvoNet has over 150 member institutes
- uncountable (meaning: many) applications
- uncountable (meaning: ?) consultancy and R&D firms

# Advantages

- Conceptual simplicity
- Outperform classic methods on real problem
- Easy to incorporate with other methods
- Parallelism
- Capability for self-optimization
- Broad applicability: handling constraints, multimodal, multiobjective, non-differentiable, non-continuous, NP-complete problems

# Conceptual Simplicity




```
Procedure  EVOLUTION_PROGRAMs
Begin
      t ← 0
      Initialize P(t)
      Evaluate P(t)
      While (not termination-condition) do
      Begin
            t ← t + 1
            Select P(t) from P(t-1)
            Alter P(t)
            Evaluate P(t)
      End
End
```

# Outperform Classic Methods

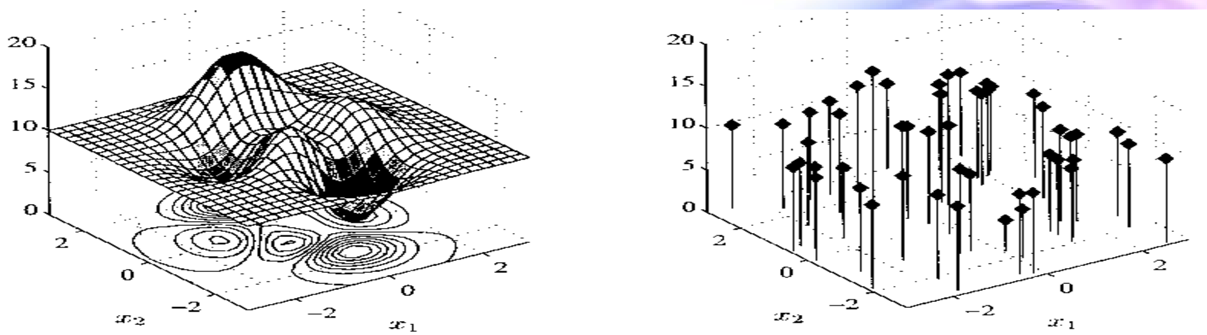


Figure 1.2 A function with three local maxima (surface plot on the left, function values at random points on the right).

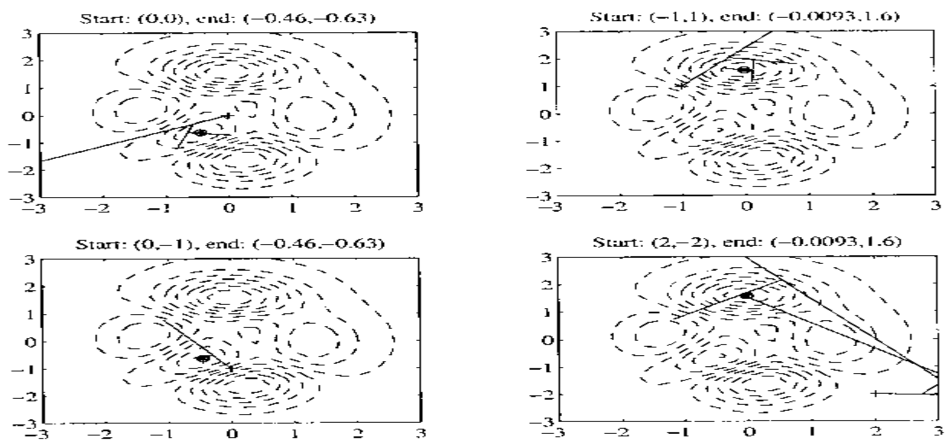



**Figure 1.3** Optimization with a the routine fminu the Matlab Optimization Toolbox. The routine is based on the BFGS secant method.

# Techniques of Soft Computibng

| | | | | | | |
|---|---|---|---|---|---|---|
| Soft Computing | = | Neural Network | + | Evolutionary Computing | + | Fuzzy Logic |
| Zadeh 1981 | | McCulloch 1943 | | Rechenberg 1960 | | Zadeh 1965 |

# Disadvantages

- No guarantee for optimal solution within finite time
- Weak theoretical basis
- May need parameter tuning
- Often computationally expensive, i.e. slow

# When should a EPs be used

- There is no rigorous answer, though many researchers share the intuitions that if the space to be searched is large, is known not to be perfectly smooth, or is not well understood, or if the fitness function is noisy, and if the task does not require a global optimum to be found – i.e., if quickly finding a sufficiently good solution is enough – a GA will have a good chance of being competitive with or surpassing other “weak” methods (methods that do not use domain-specific knowledge in their search procedure).

# Domains of Application

- Numerical, Combinatorial Optimization
- System Modeling and Identification
- Planning and Control
- Engineering Design
- Data Mining
- Machine Learning
- Artificial Life

:

:

# Research

- 2015, “Enhancing Differential Evolution Utilizing Eigenvector-Based Crossover Operator,” *IEEE Transactions on Evolutionary Computation*.(2016Ranking = 1/133 = 0.7%; IF = 10.629)
- 2015, “Improving differential evolution with successful-parent-selecting framework,” IEEE Transactions on Evolutionary Computation, (SCI, EI) (2016Ranking = 1/133 = 0.7%; IF = 10.629).
- 2015, “Constraint-activated Differential Evolution for Constrained Min-max Optimization Problems: Theory and Methodology,” Expert Systems with Applications. (2016Ranking = 3/83 = 3.6%; IF = 3.928)
- 2015, “ Fast large-scale image enlargement method with a novel evaluation approach: benchmark function-based peak signal-to-noise ratio” IET Image Processing. (SCI, EI)
- 2016, “Constrained min-max optimization via the improved constraint-activated differential evolution with escape vectors,” Expert Systems with Applications, vol. 46, pp. 336-345. (SCI, EI) (2016Ranking = 3/83 =3.6%; IF = 2.982)
- 2017, “Evolutionary fuzzy block-matching based camera raw image denoising,” IEEE Transactions on Cybernetics. (2016Ranking = 5/133 = 3.7%; IF = 7.384)
- ….

# Sources of Information

- Books
- Journals
- Conferences

# Books

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- L. Davis, The Handbook of Genetic Algorithms, Van Nostrand & Reinhold, 1991
- D.B. Fogel, Evolutionary Computation, IEEE Press, 1995
- D.E. Goldberg, Genetic Algorithms in Search, Optimisation and Machine Learning, Addison-Wesley, ‘89
- J. Koza, Genetic Programming, MIT Press, 1992
- Z. Michalewicz, Genetic Algorithms + Data Structures = Evolution Programs, Springer, 3rd ed., 1996
- H.-P. Schwefel, Evolution and Optimum Seeking, Wiley & Sons, 1995

# Journals

- IEEE Transactions on Evolutionary Computation, since 1996
- Evolutionary Computation, MIT Press, since 1993
- BioSystems, Elsevier, since <1986

# Conferences

- ICGA, USA, 1985 +2
- PPSN, Europe, 1990 +2
- FOGA, USA, 1990 +2
- EP, USA, 1991 +1
- IEEE ICEC, world, 1994 +1
- GP, USA, 1996 +1

# Summary

Evolution Programs :

- is based on biological metaphors
- has great practical potentials
- is getting popular in many fields
- yields powerful, diverse applications
- gives high performance against low costs
- AND IT'S FUN !

# Q & A