### Origin of the Species

<table>
<thead>
<tr>
<th>Million Years Ago</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>?</td>
<td>Origin of Life</td>
</tr>
<tr>
<td>3500</td>
<td>Bacteria</td>
</tr>
<tr>
<td>1500</td>
<td>Eukaryotic Cells</td>
</tr>
<tr>
<td>600</td>
<td>Multicellular Organisms</td>
</tr>
<tr>
<td>1</td>
<td>Human Language</td>
</tr>
</tbody>
</table>

![Evolution illustration](http://ncra.ucd.ie)
Origin of the Species

Milestones

~ 200y.a. Jean-Baptiste Lamarck:
  Lamarckism or soft-inheritance:
  - Passing of lifetime acquired characteristics.

~ 140y.a. Charles Darwin:
  Theory of Natural Selection:
  - Natural vs. Artificial Selection (a.k.a. breeding).

~ 140y.a. Gregor Johann Mendel:
  Mendelian Inheritance:
  - Basis of Modern Genetics.

~ 80y.a. Fisher, Haldane & Wright:
  Population Genetics:
  - Combined evolution, genetics, and statistical probabilities.
Origin of the Species

**Milestones**

∼ 60y.a. **James D. Watson**:
Helix structure of DNA:
- Watson-Crick base paring of nucleotides.

∼ 60y.a. **Francis Crick**:
Helix structure of DNA:
- Watson-Crick base paring of nucleotides.

∼ 40y.a. **Motoo Kimura**:
Neutral Theory of Molecular Evolution:
- Variation at molecular level likely result of genetic drift.

∼ 40y.a. **Richard Lewontin**:
Molecular Diversity:
- Evolution at molecular level.
Origin of the Species

But...

Epigenetics: back to Lamarckism!
Chromosomes:
- composed of Deoxyribonucleic acid: **Genetic fingerprint of individuals**;  
- Located in nucleus (eukaryotes) or cytoplasm (prokaryotes);  
- Double helix of base pairs: Adenine, Thymine, Guanine and Cytosine;  
- Sequence of genes;  
- Exons and Introns;  
- Genome.
Sequence Space

- Individual
  - Chromosome
  - Gene
  - Exon
  - Intron
  - Genome

- Genome lives in Sequence Space

<table>
<thead>
<tr>
<th>Organism</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Virus</td>
<td>10000</td>
</tr>
<tr>
<td>Bacterium</td>
<td>4 Million</td>
</tr>
<tr>
<td>Humans</td>
<td>3.5 Billion</td>
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</table>
Evolutionary Computation

**Brief History**

- Evolution with computers can be traced back to 1948 (Turing);
- First PhD in Computer Science (John Holland, 1959) popularised Genetic Algorithms;
- 1960s: Genetic Algorithms vs. Evolution Strategies (Evolutionary Programming);
- 1985: First Conference;
- 1992: Genetic Programming (1st instance 1958!);
- 1990s: Unified under EC.
Evolutionary Computation

- Evolution Strategies
- Evolutionary Programming
- Genetic Algorithms
- Genetic Programming
- Differential Evolution

- Grammatical Evolution
- Grammatical Evolution by Grammatical Evolution
- \( \pi \) Grammatical Evolution
- Grammatical Differential Evolution
Evolutionary Computation

\[ x[t + 1] = r(v(s(x[t]))) \]

**Evolutionary Algorithm**

- Initialise Population;
- While (termination condition FALSE):
  - select Parents;
  - create Offspring;
  - Update Population;
- EndWhile
Polar Bear Example

- World’s largest carnivore;
- Descendent of Brown Bear;
- Separate evolution for last 4-5 million years;
- Clear/White Fur;
- 4 Legs;
- Furred Soles;
- Broad Forepaws;
- Large and Stocky:
  - 1.8-2.5m length (tip of nose to tail);
  - 150-800kg.

<table>
<thead>
<tr>
<th>Colour</th>
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<tr>
<td>White</td>
<td>4</td>
<td>Furred</td>
<td>30.4cm</td>
<td>2.2m</td>
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Category  Integer  Boolean  Float  Float  Float
Polar Bear Example

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<td>4</td>
<td>Furred</td>
<td>29.9cm</td>
<td>1.1m</td>
<td>203.7kg</td>
<td>3 years</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>4</td>
<td>No Fur</td>
<td>15.4cm</td>
<td>1.8m</td>
<td>771.6kg</td>
<td>10 years</td>
<td></td>
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Average Fitness of Population = 11 years
Best Individual Fitness = 20 years
Polar Bear Example (Selection)

- Fitness=10: 30%
- Fitness=3: 9%
- Fitness=10: 30%
- Fitness=20: 61%
## Polar Bear Example (Variation)

### Parents:
<table>
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### Offspring:
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<td>1.7m</td>
<td>741.6kg</td>
<td>7 years</td>
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Polar Bear Example (Replacement)

Several approaches possible;
Generational population (offspring replace parents).

New Population:

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Average Fitness of Population = 15 years
Best Individual Fitness = 23 years
Evolutionary Computation

Black Art of EC

- Population-based search;
- Stochastic;
- Design representation;
- Design fitness measure;
- Design algorithm (e.g., balanced variety generation operators and selection pressure).
Evolutionary Computation

Applications

- Too many to list!
- Engineering
- Design
- Sound Synthesis
- Circuit Design
- Games
- Financial Modelling
- Bioinformatics
- Human-competitive results
Evolutionary Computation

Funes & Pollack (1997)
Evolutionary Computation

Karl Sims (1991)
Evolutionary Computation

Al Biles (1993)
GenJam
Evolutionary Computation

Natural Computing Research and Applications (NCRA) Group
Evolutionary Computation

[video]
Next Classes

▶ Lecture Tuesday 17th September 15h - 16h (Genetic Algorithms - Mike);
▶ Lecture Thursday 19th September 15h - 16h (Genetic Programming #1 - Miguel);