BioComputer

-The New Era

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A. **Introduction**
   1. Brief History.
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   2. Overview for solving a problem using bio computing.
   3. Applications of bio computing.

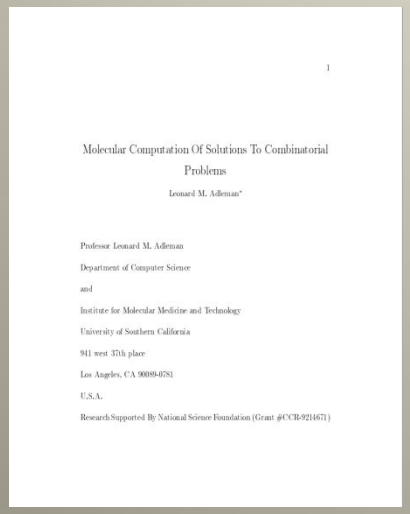
C. **Future**
   1. Medical Treatment
   2. Artificial Intelligence

History…

1994, Leonard M. Adleman,
"Molecular Computation of Solutions To Combinatorial Problems ".

1995.8, 200 Experts
admits the Feasibility of DNA computer

2011, Jerome Bonnet,
Building a transistor out of DNA and RNA at Stanford University



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Molecular Computation Of Solutions To Combinatorial Problems

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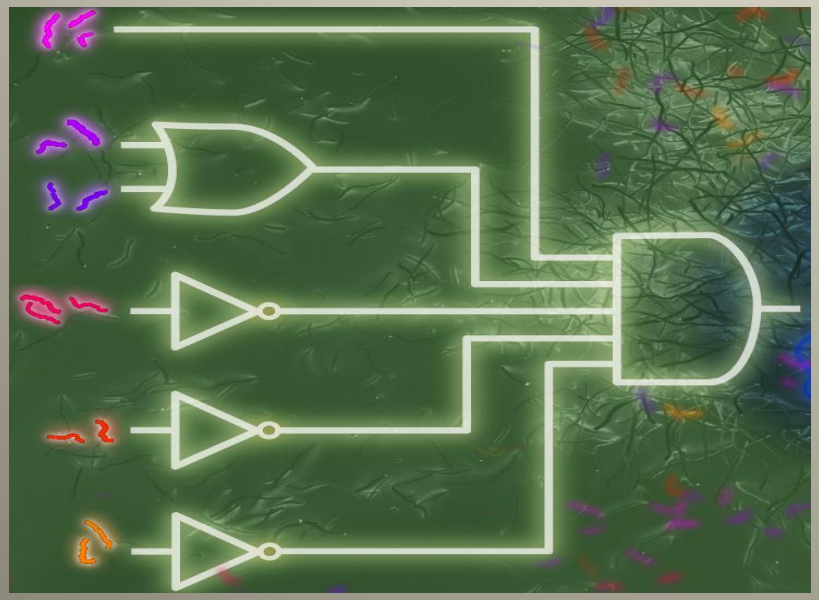
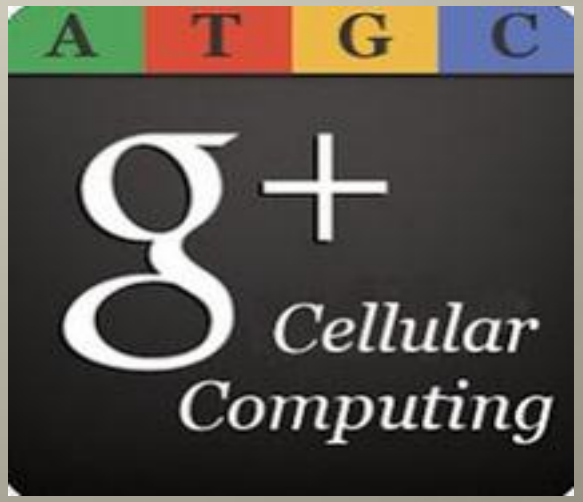
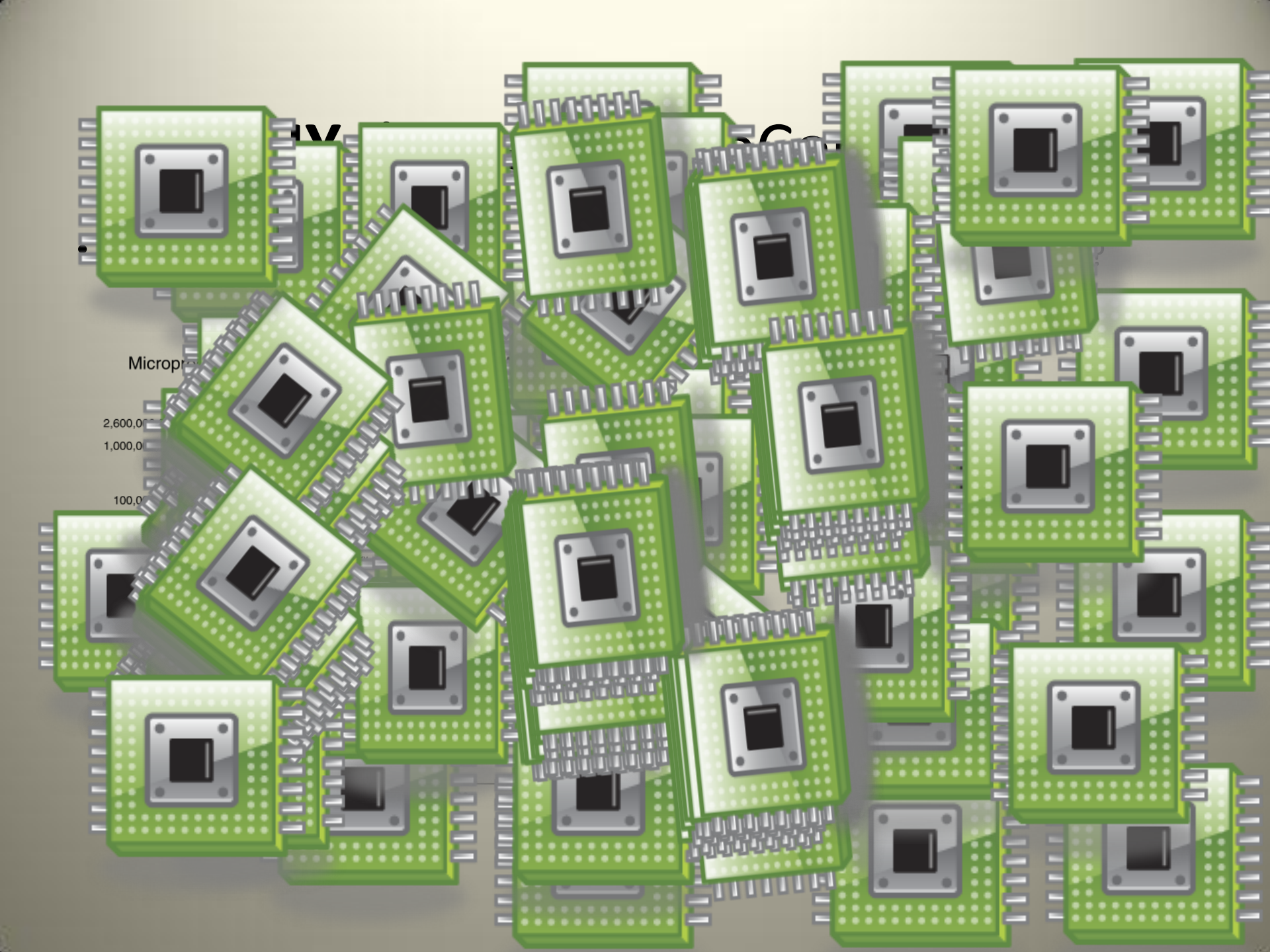
WHAT is a BioComputer?

- Use systems of biologically derived molecules, such as **DNA** and **proteins** to perform **computational calculations**.
- Y=(A+B)C+(A+B')(C+D') ⇔ Y = (+) +…..



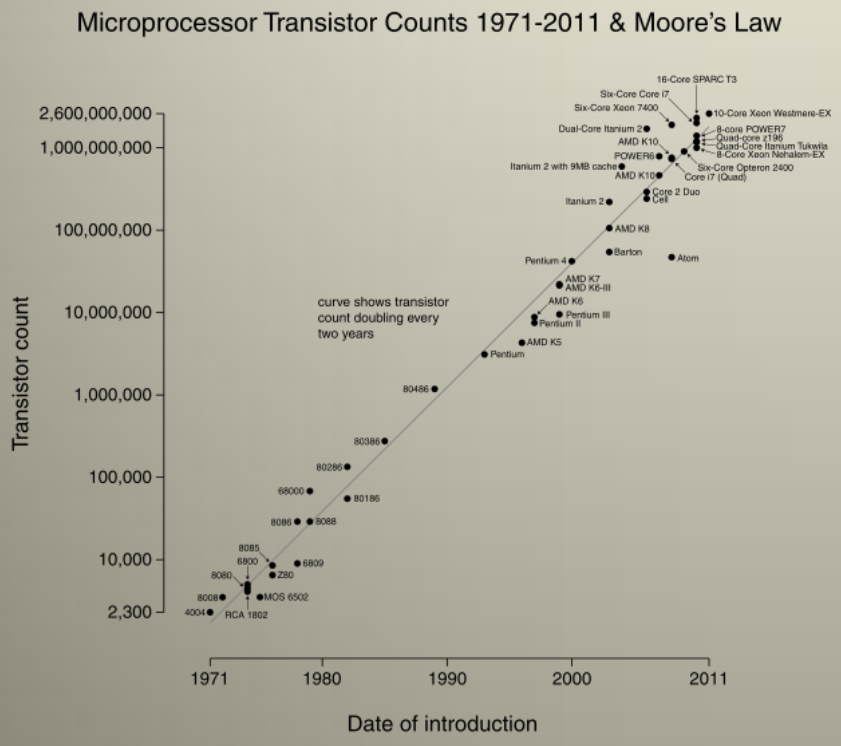


http://www.kurzweilai.net



WHY do we use BioComputer?

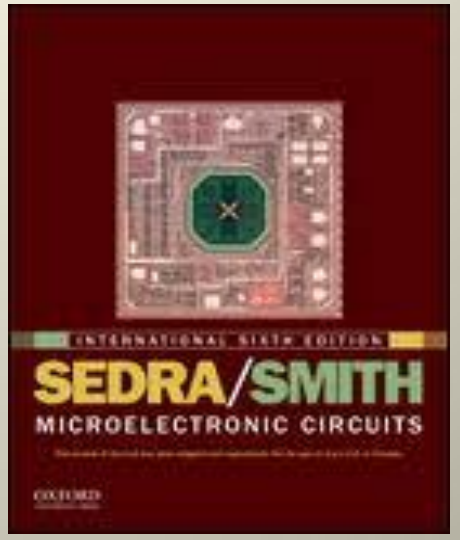
Moore's Law

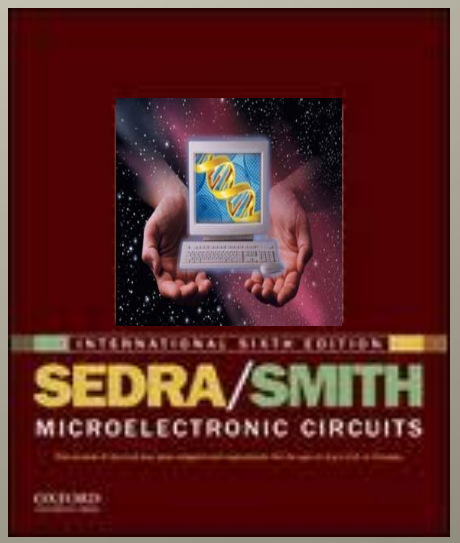


What will happen after 2011?

WHY do we use BioComputer?

- **Pros**
  1. Multi-processor.
  2. Low Energy Cost.
  3. Little Waste.
  4. High Artificial Intelligence (AI).
  5. Self-Recovery.
  6. Massive Memory
- **Cons**
  1. Error and unreliable
  2. Not transmittable





DNA Computing

- DNA is a polymer
  - Sugar-Phosphate-Base
  - Bases held together by H bonding to the opposite strand.
  - Double-strand structure.
- 4 Base pairs
  - A, T, C, G
  - Pair A-T and C-G on complementary strands. (Watson-Crick Complementary)

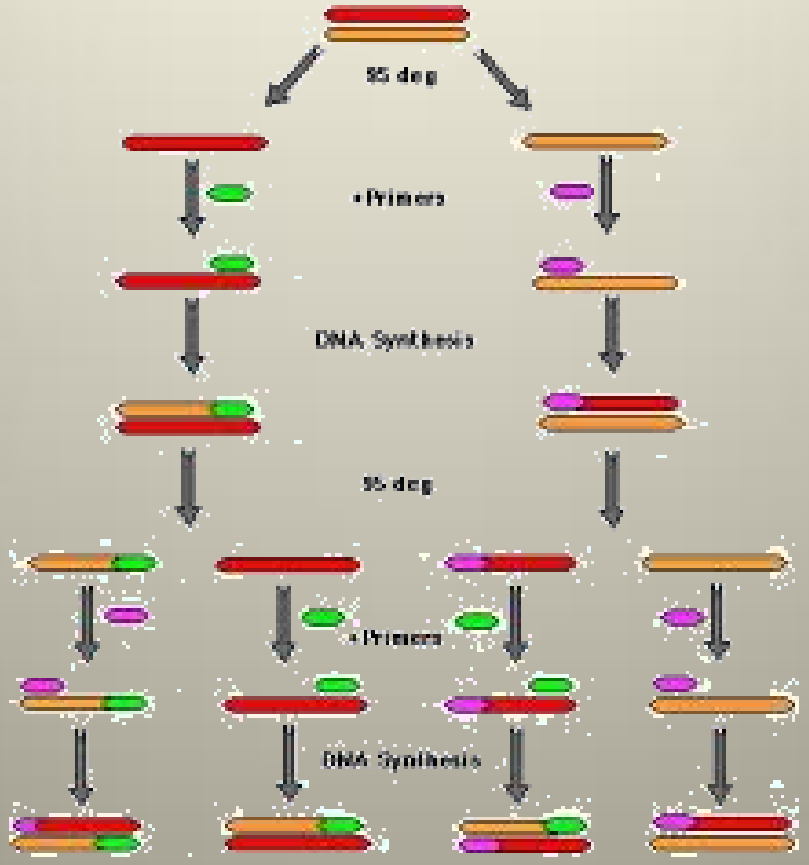
DNA Computing

- Massive Parallelism of DNA Strands
  - 10^-6 g of DNA composed by strands of 10^3 bases each contains 3.03 x 10^12 mol.
- Massive Storage
  - 6 x 10^16 molecules per ml.
  - We can effectively store 60000 Terabytes of memory.
- Methods
  - Computation, input, output occur in test cubes.
  - Amplified by PCR
  - Electrophoresis

DNA Computing - PCR

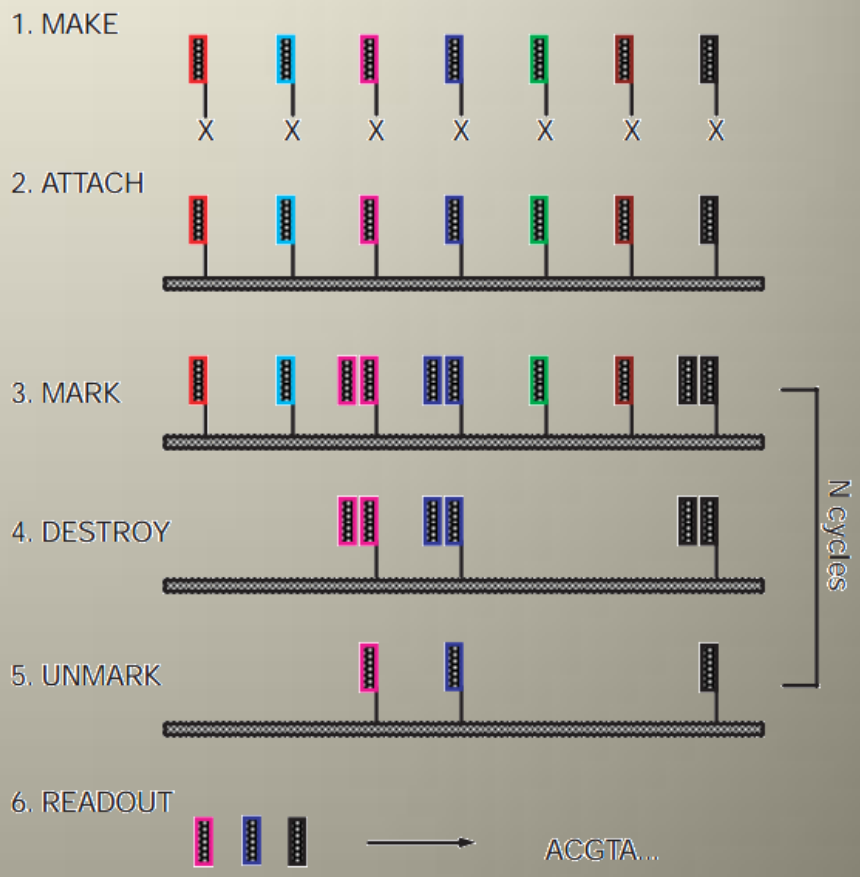
- To store/edit/read information from/to DNA, we need multiple copies.
- How to read base pairs that are angstroms in size?
  - Not possible to read directly. Instead, we use chemical techniques to detect it.
- PCR
  - Massively Replicate DNA Sequences
  - Generate a replica a time.
  - Repeat the progress and the amount of DNA grows exponentially.

DNA Computing - PCR



DNA Computing on Surface

- Overview
  - MAKE
  - ATTACH
  - MARK
  - DESTROY
  - UNMARK
  - READOUT
- At the end of N cycles, only the strands satisfy the problem remain.

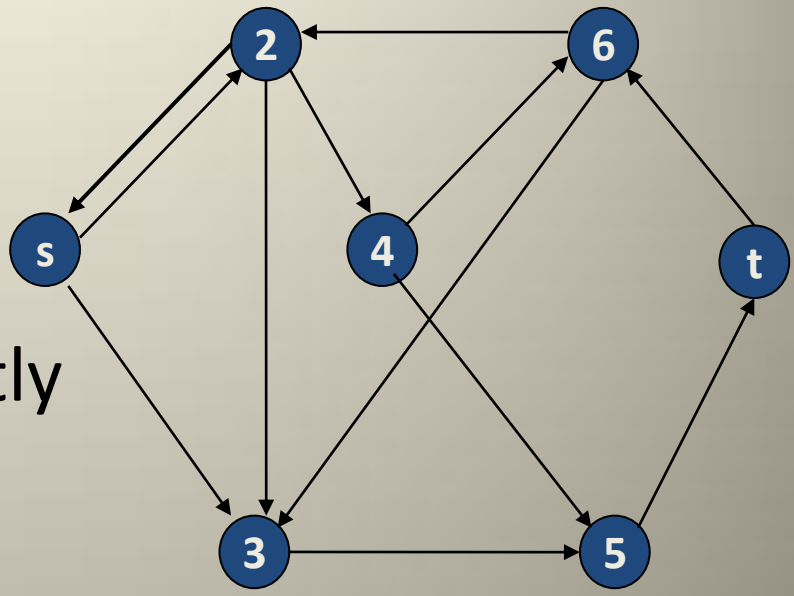


Applications of DNA Computing

- Solving NP problems
  - Problems that can't not be deterministically solved in polynomial time.
  - Hamiltonian Path Problem
  - SAT Problem
  - Maximum Clique
- The solution based on massive parallelism.
- Watson-Crick complementary is used to select and filter out solutions as they are processed.

DNA Computing - HPP

1. Generate random paths
2. Keep paths start from source and end at sink.
3. Keep those that visit exactly n vertices.
4. Keep those that visit each vertex at least once.
5. If any path remains, return “YES”. Otherwise return “NO.”



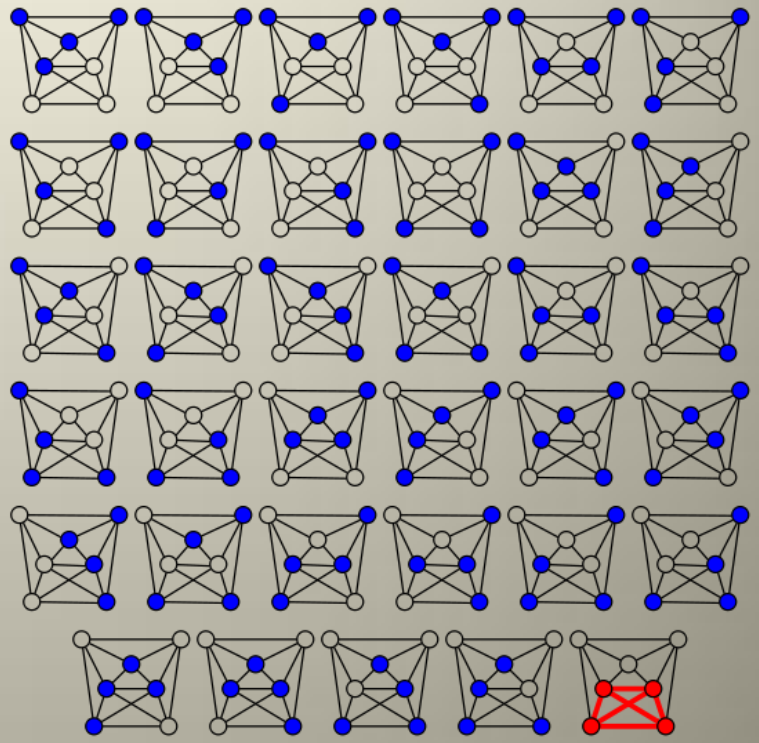
DNA Computing – SAT Problem

- Given a Boolean expression, is there some assignment of TRUE and FALSE to each variable that make the entire expression TRUE?

$$E = (x_1 \vee \neg x_2 \vee \neg x_3) \wedge (x_1 \vee x_2 \vee x_4)$$

DNA Computing – Maximum Clique Problem

- Consider a graph, we want to find the largest subset of vertices whose elements connect to all other elements with edges.

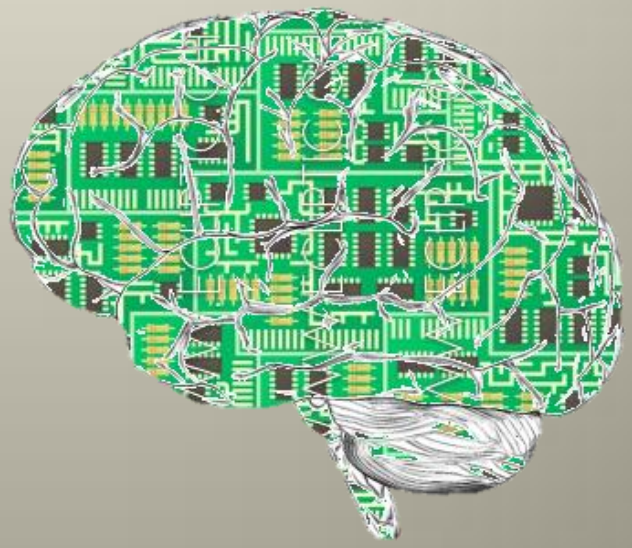


DNA Computing - Pros and Cons

- Pros
  - Outshine conventional silicon computers on parallelism.
  - Huge storage space.
  - Low power dissipation.
- Cons
  - Unit operations is far slower than silicon computers.
  - Error and unreliable
  - Not transmittable
  - No generality.

Future Work

- 1. Medical Treatment
- 2. Artificial Intelligence



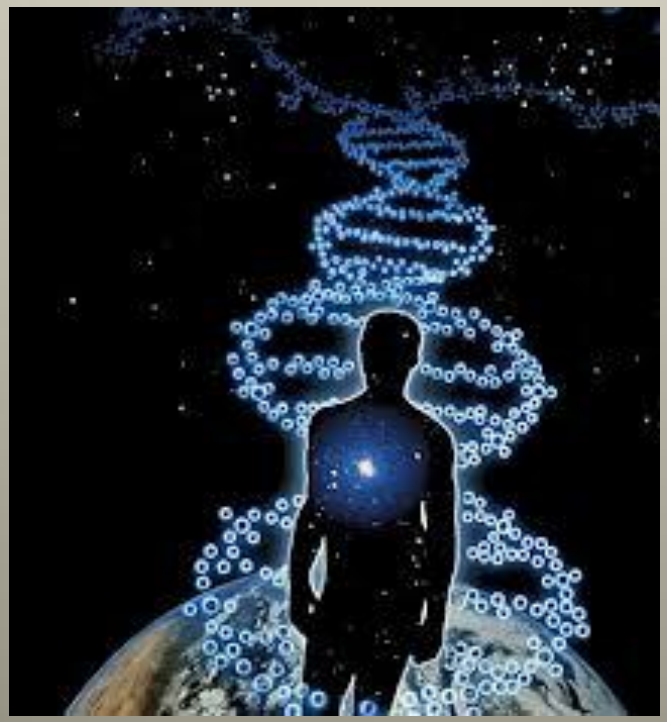
Medical Treatment

- **Three Programmable Modules**
  - 1. Input Module
    - Detection!!!
  - 2. Computation Module
    - Deduction!!!
  - 3. Output Module
    - Drug Release!!!

- Inputs, Outputs, Software and Hardware are all composed by DNA molecules.

Medical Treatment

- We can use BioComputer to diagnose **cancer** by analyzing RNA, and to release anti-cancer drugs controlled by DNA.

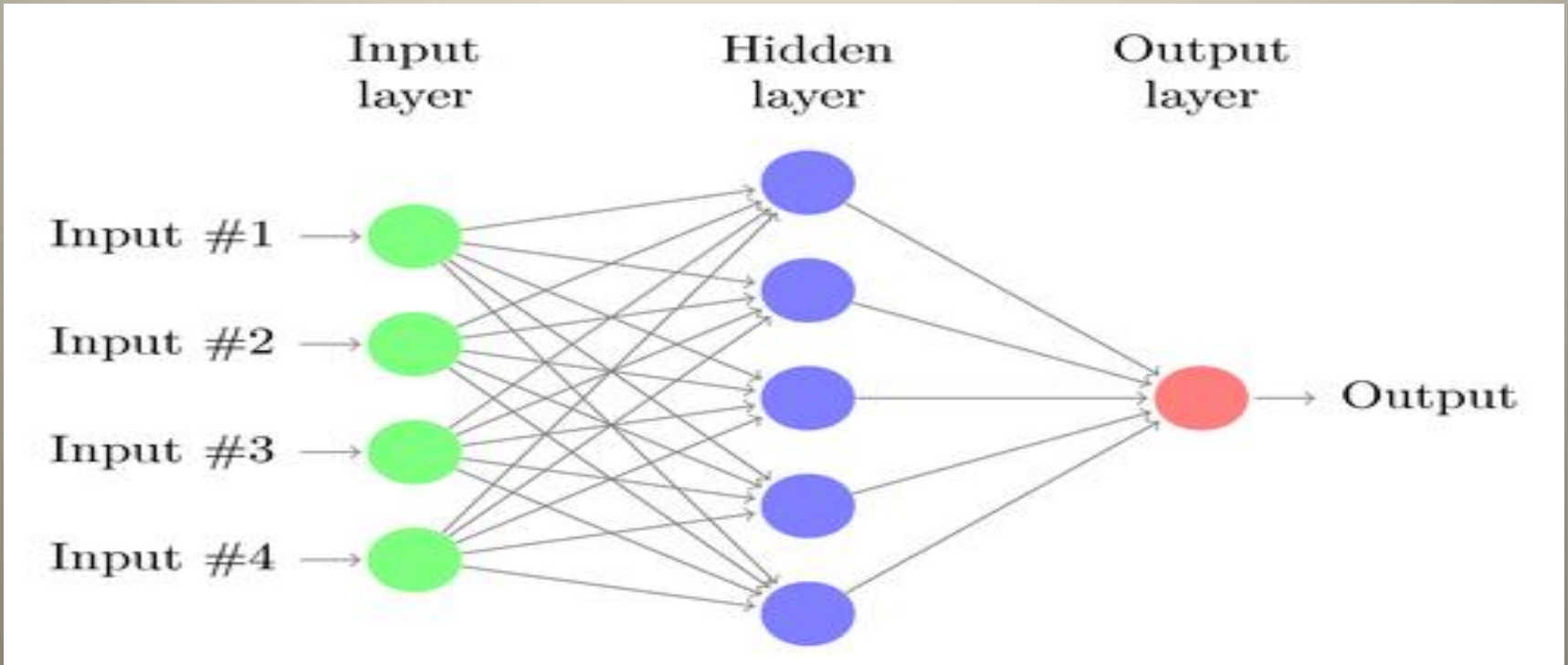


Medical Treatment

- You just need to buy a BioComputer capsule, and it can serve as a **doctor** and **medicine**.

Artificial Intelligence

- **Neural Network**



Artificial Intelligence

1. Parallel Computation
   - All can work at same time!!!
2. Large Memory
   - 1 cm^3 DNA can store much more data than 1000000000000 CDs!!!

The End
Thanks for Listening