DARPA Bio Futures

Adding the “Bio Dimension” to DARPA Futures

Stephen L. Squires

1999.05.19

What are we doing?

- Reflecting on the past
- Recognizing trends and limits
- Formulating alternative futures
- Developing a strategic vision
- Stimulating strategic processes
- Moving toward advanced futures

Reflecting on the past

- Over 50 years of ***accelerating advance*** ...
- The role of
  science,
  technology,
  applications.
- The role of DARPA in the
  national and global
  system context.

Recognizing trends and limits

- The information technology revolution
  enabled by microelectronics
- The revolutions in biology with
  minimal coupling to info and micro
- The increasingly pervasive use of
  information technology in
  science, technology, society
- The potential of coupling to biology

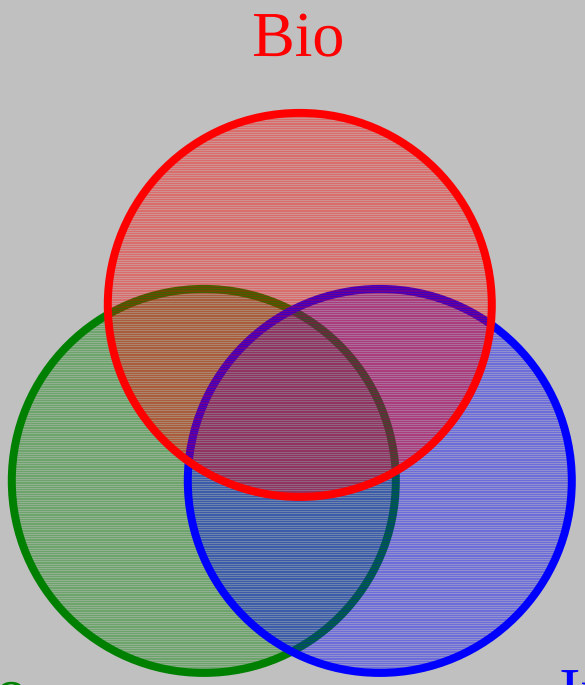
Formulating alternative futures

- Recognize the potential of increased coupling among [Bio:Info:Micro]
- Imagine the scientific discovery of fundamental devices at the intersection
- Imagine their transformation to new scalable systems and applications

Why this is important ...

- Defense Challenges
  - Bio Defense
  - Human Interfaces
  - Others?
- DARPA Opportunities
  - Enabling new mission capabilities
  - Stimulating new science and technology
  - Building on DARPA Strengths

Interactions

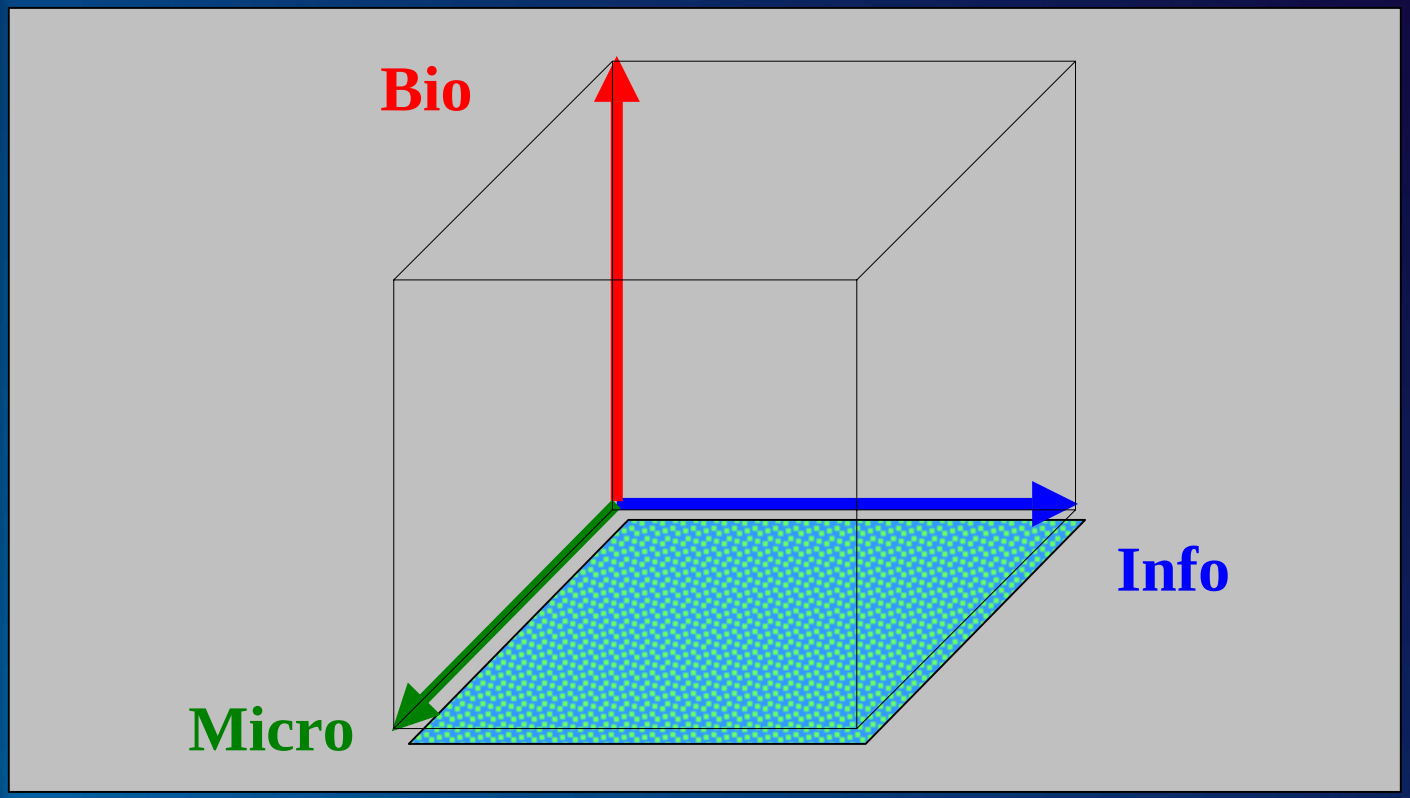


Scale

- … up toward galactic
- 10^{24} *O(Avogadro)*
- 10^{21}
- 10^{18} E Exa
- 10^{15} P Peta
- 10^{12} T Tera
- 10^{9} G Giga
- 10^{6} M Mega
- 10^{3} K Kilo
- 10^{0} (1)

- 10^{-3} milli
- 10^{-6} micro
- 10^{-9} nano
- 10^{-12} pico
- 10^{-15} femto
- 10^{-18} atto
- … down into sub atomic

The [Bio:Info:Micro] Space



1999.05.19 Each dimension is Log(scale) with origin at Log(1)

Fundamental Devices

A Generic 21st Century Characterization

- Enables fundamental advance
- Functional unit of replication
- Scalable production system
- Integrable into systems

The details are different for each kind ...

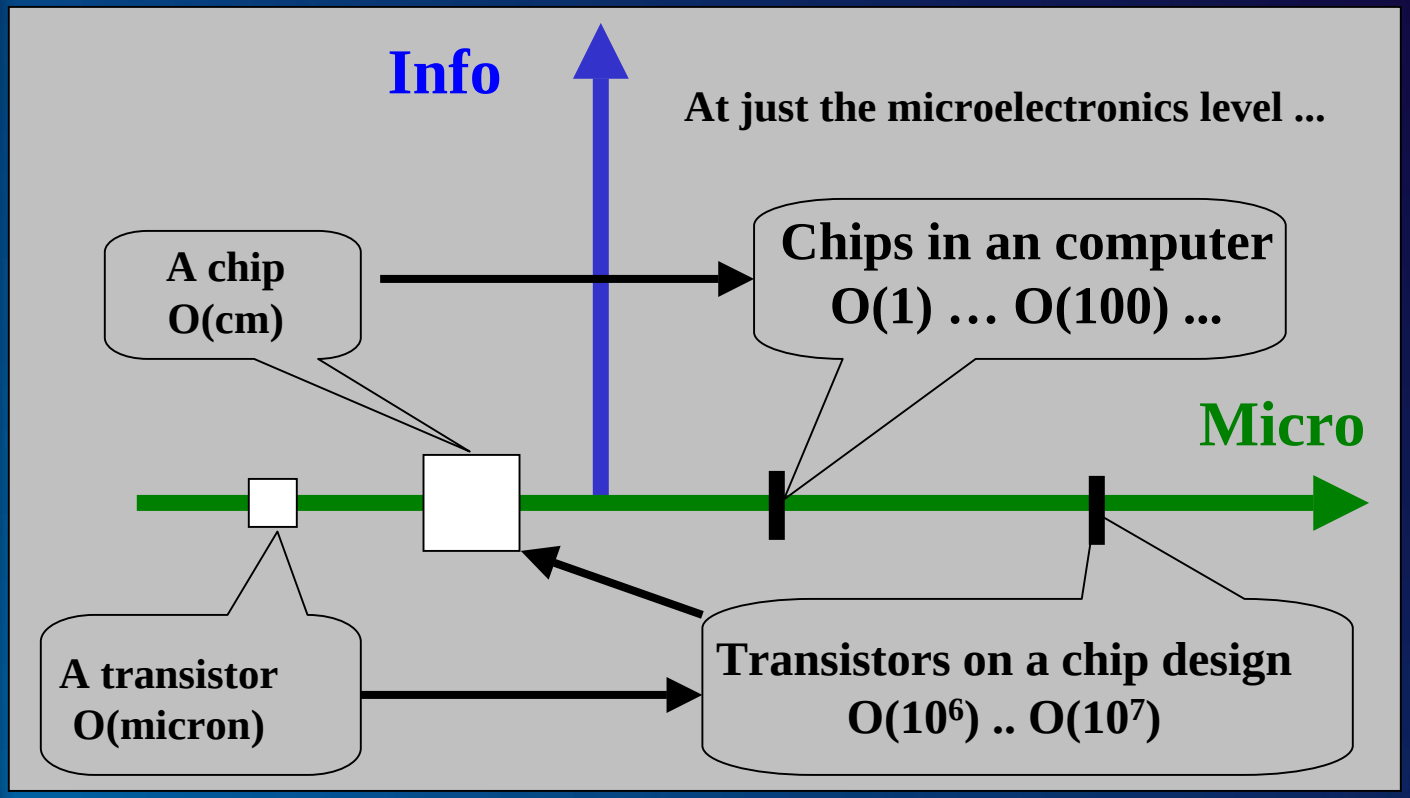
“Solid State” Technologies enable [Micro:Info]

Transistors, Lasers, Displays and “Magnetics”

1999.05.19

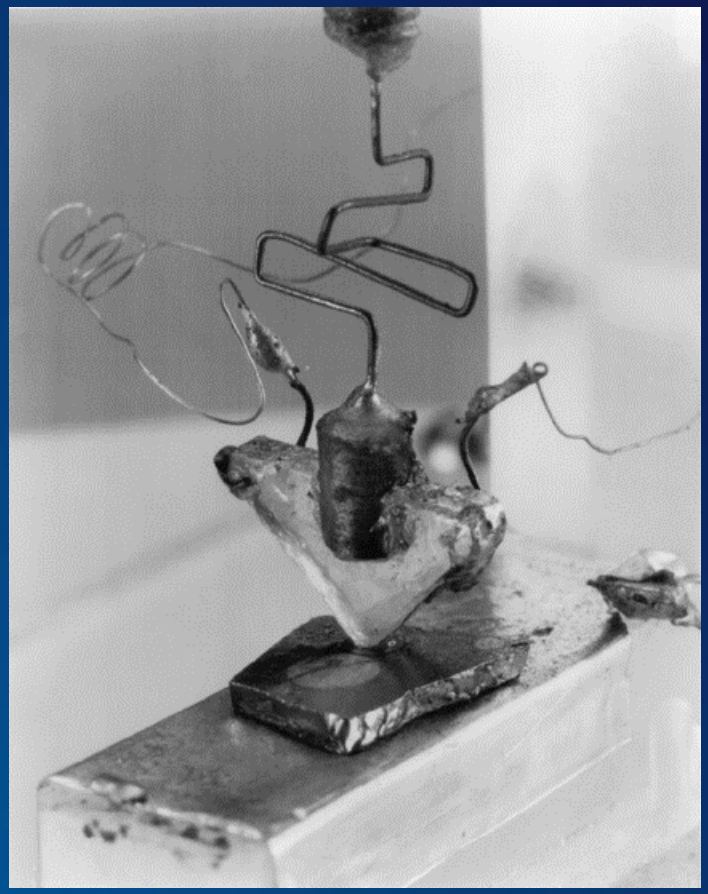
[Micro:Info]

(For t = 2000)

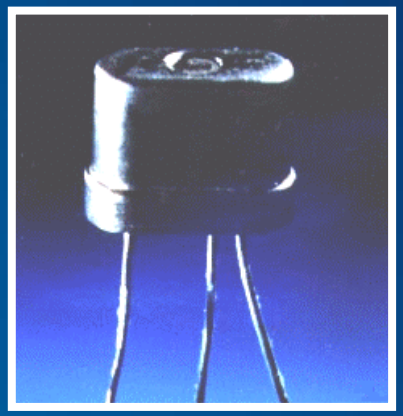


1999.05.19

The transistor invention ...

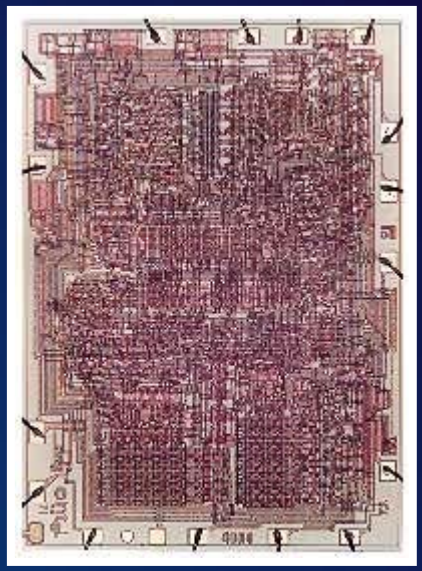


… from Transistors to …



Transistor
in a Can

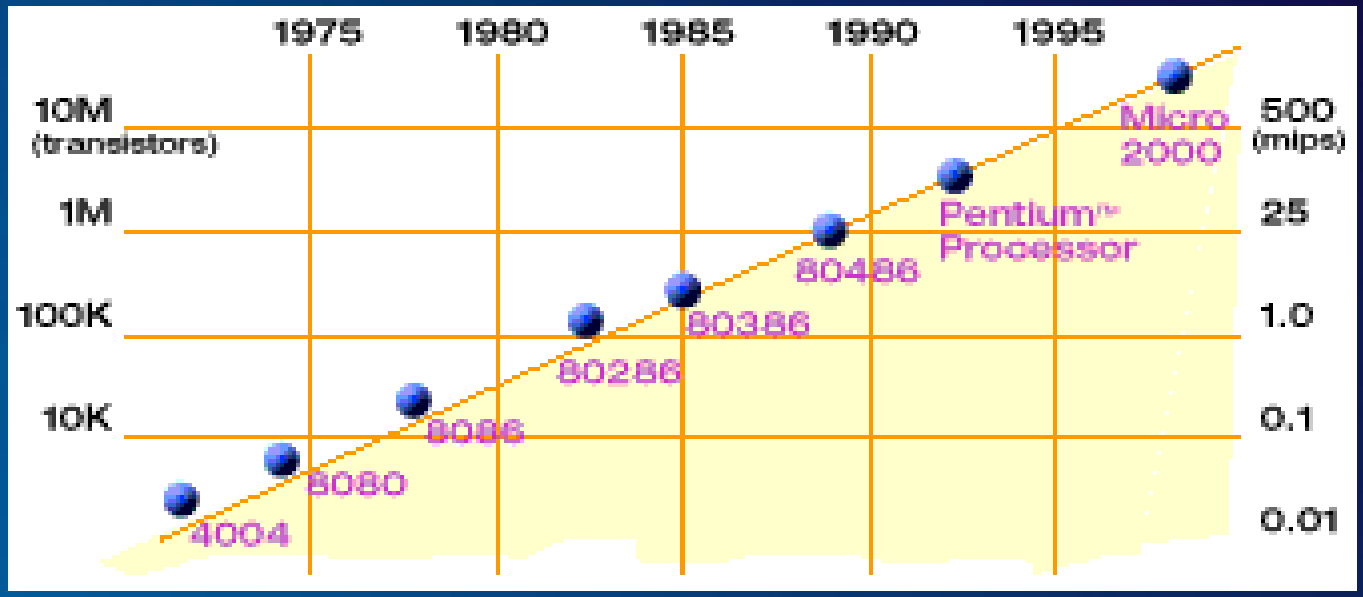
Integrated Circuit
held by tweezers



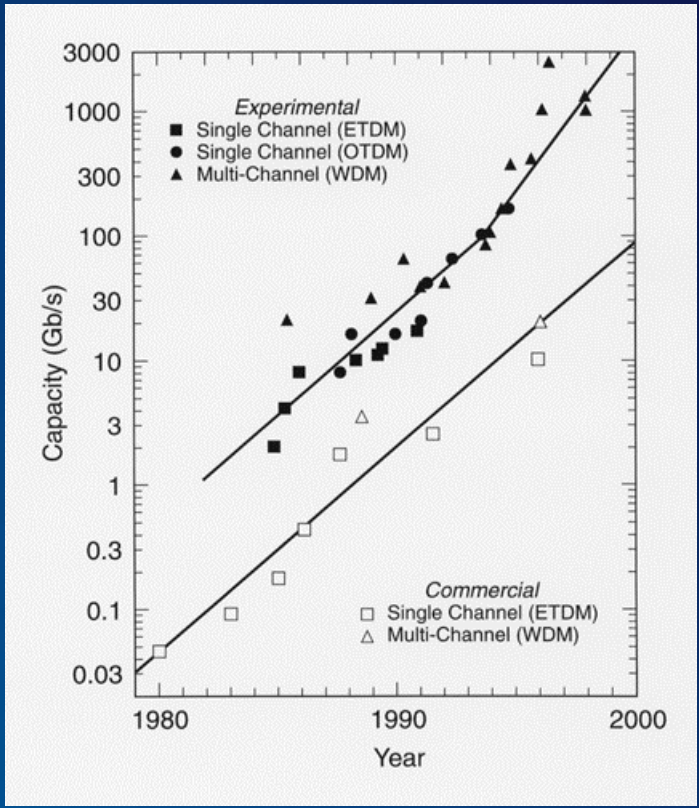
Microprocessor
photomicrograph

1999.05.19

Moore's Law

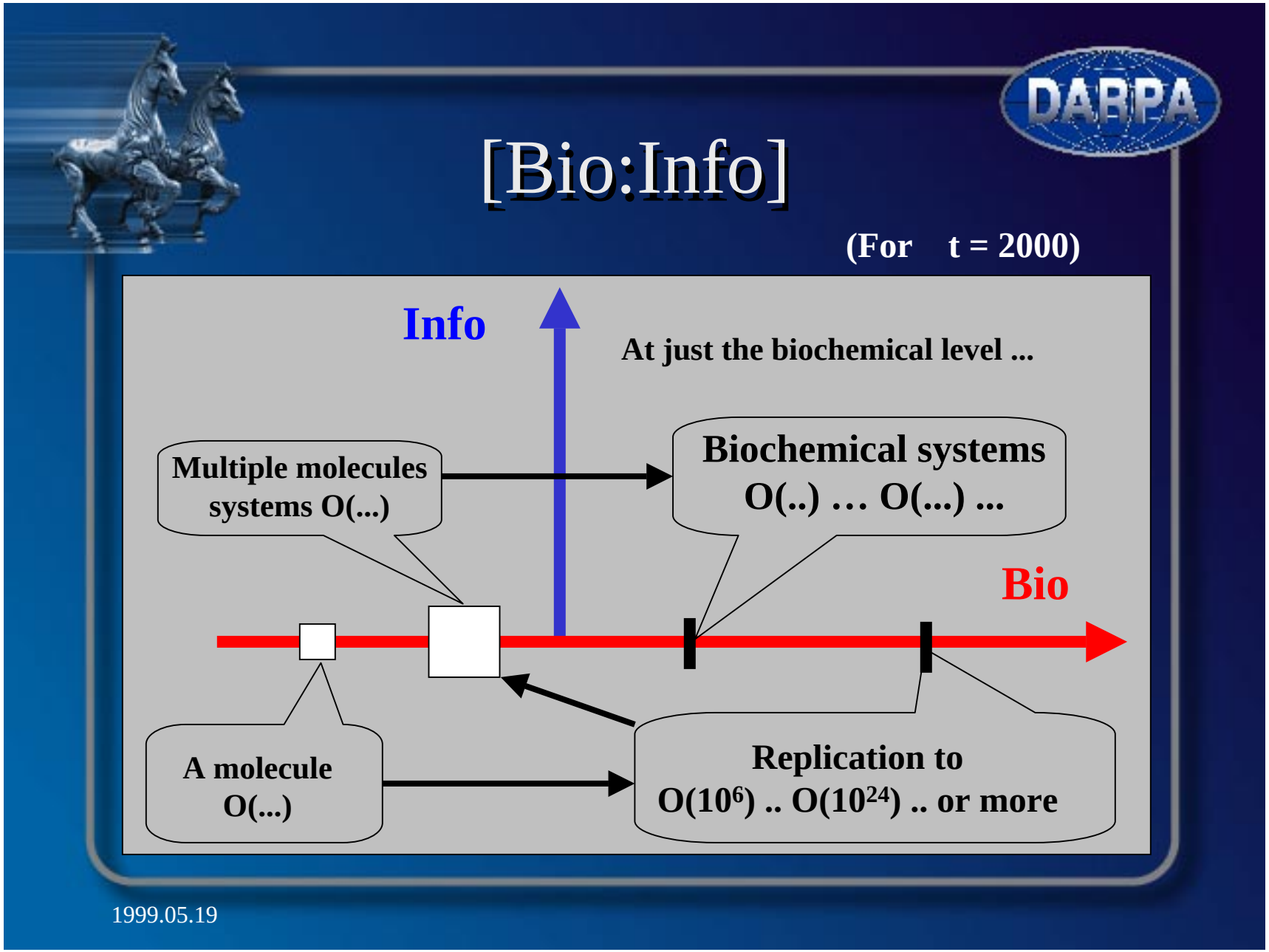

1975
1980
1985
1990
1995
10M
(transistors)
1M
100K
10K
500
(mips)
25
1.0
0.1
0.01
4004
8080
8086
80286
80386
80486
Pentium™
Processor
Micro
2000

Photonics Curves

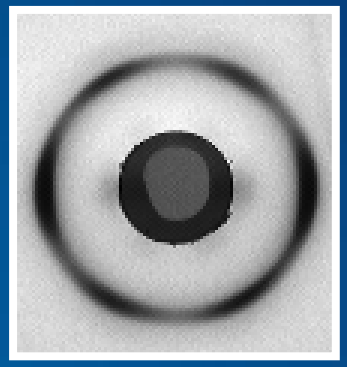


“Bio State” Technologies enable [Bio:Info:Micro]

1999.05.19

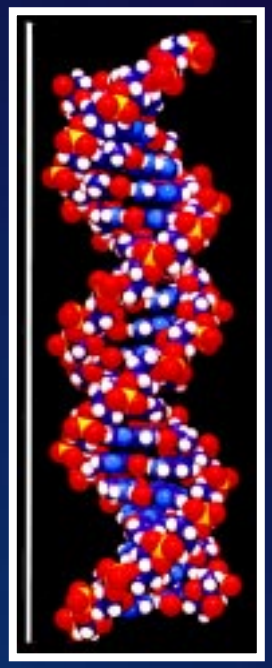

[Bio:Info]
DARPA
(For t = 2000)
Info
At just the biochemical level ...
Multiple molecules systems O(...)
Biochemical systems O(..) … O(...) ...
Bio
A molecule O(...)
Replication to O(10^6) .. O(10^24) .. or more
1999.05.19

The DNA discovery ...



X-ray crystallography

Description in Nature

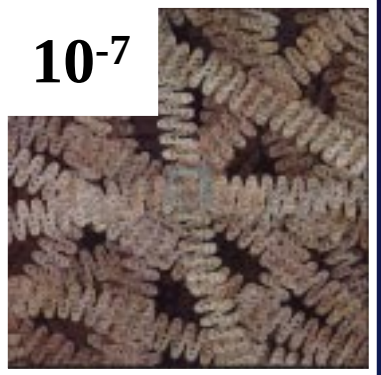


3-D Model

DNA-scale Devices

meter

10^{-7}

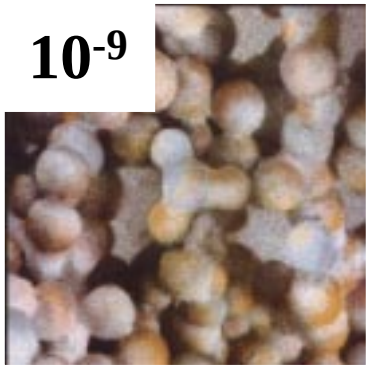


Strands of DNA

10^{-8}

The structure of DNA

10^{-9}



The molecules of DNA

1999.05.19

Cell-scale Devices

meter

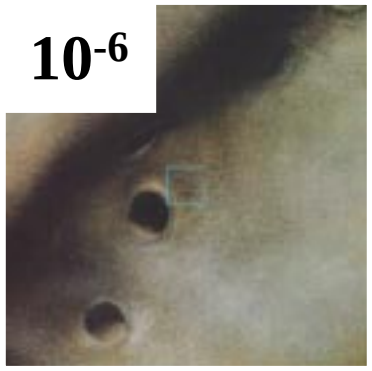
10^{-4}

Micro-organisms

10^{-5}

A lymphocyte

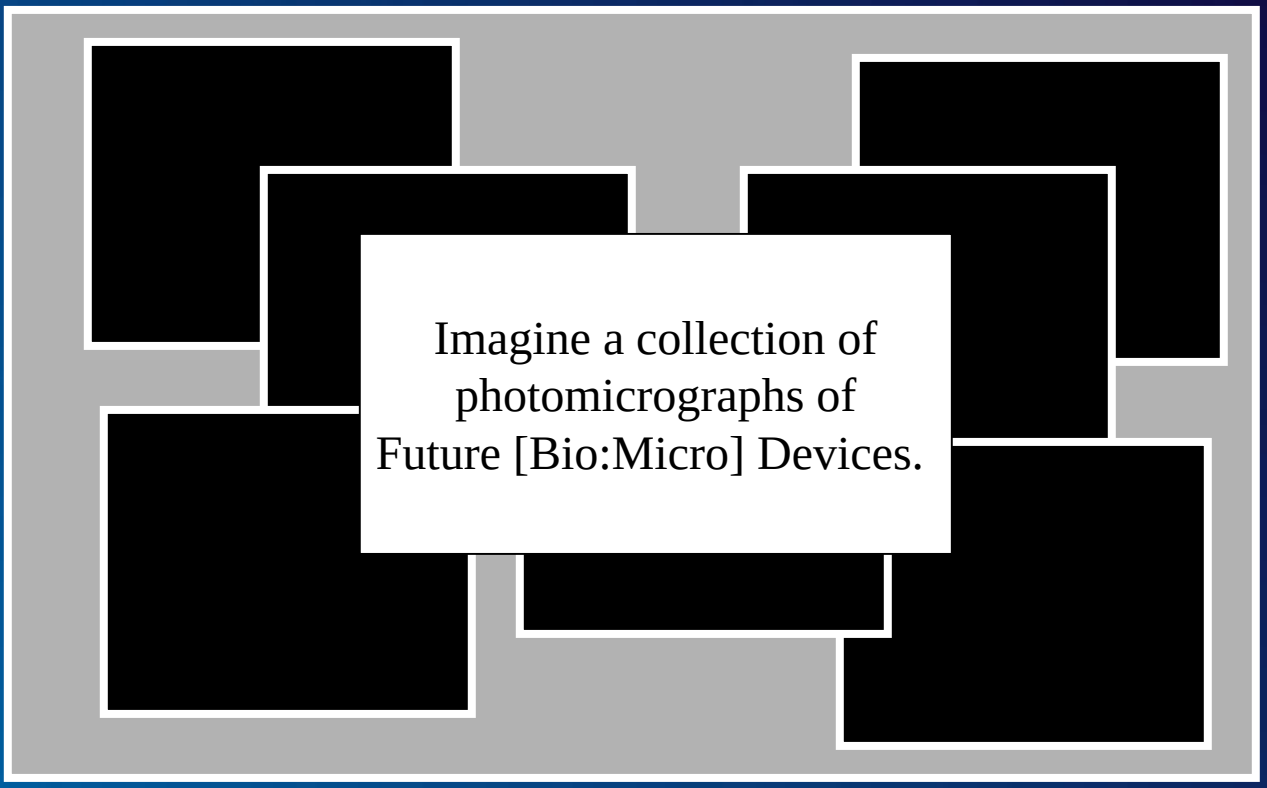
10^{-6}



The nucleus of the cell

1999.05.19

[Bio:Micro] Devices



Imagine a collection of photomicrographs of Future [Bio:Micro] Devices.

Developing a strategic vision

- Stimulate the formation of interdisciplinary research activities focused on fundamentals of the interactions in [Bio:Info:Micro]
- Enable the transition of scientific discoveries into prototype technologies that can be experimentally applied
- Enable the development of new capabilities in realistic system contexts

Stimulating strategic processes

- Leverage existing Bio research activities
- Couple to Info and Micro research
- Transition to IT-based processes
- Develop new “devices”
- Imagine new capabilities
- Transition imagination toward technology
- Establish fundamentally new capabilities

Enable IT-based ...

Measurement

Analysis

Design

Prototyping

Integration

Collaboration

All accessible over the Net

Preparing for the future

- Visiting advanced research sites
  - Aggressive listening
  - Trends, limits, challenges, opportunities
  - Investment strategies
- Planning [Bio:Info:Micro] meetings
- Planning joint program approaches
- Planning for ***future*** pilot projects