Nanomedicine

Danny Porath 2002

(http://www.foresight.org/Nanomedicine/)
Recommendation for the presentation

1. Prepare for 10 minutes - about 10 slides.

2. Be focused and practical.

3. Rehearse loudly with the “mirror” and a friend.

4. Prepare answers and slides for “possible” questions.

Links to NST

http://www.foresight.org/Nanomedicine/
http://www.foresight.org/Nanomedicine/Gallery/Captions/index.html
http://www.hgc.cornell.edu/index.html
http://www.aep.cornell.edu/eng10_offsite.cfm?URL=...Ecornell%2Eedu%2Fdefault%2Ehtm
http://nanobio.snu.ac.kr/eng/index.html
http://www.matar.ac.il/eureka/newspaper15/dreams-3.asp
http://web.syr.edu/~akwok/
Based on Works of…….

1. Harold Craighead - Cornell
2. Katja Juhola - Tampere
Outline:

1. Towards the presentation
2. Nonmedicine and Nanomedicine
3. Summary of the course
Homework 13

1. Read the paper:
   “Less is more in medicine”, By: A.P. Alivisatos

2. Read the paper:
   “The once and future nanomachine”, By: G.M. Whitesides
   Scientific American, September 2001 pp. 78.

3. Read the paper:
NanoScience
or
NanoNonsense?
"Like primitive engineers faced with advanced technology, medicine must 'catch up' with the technology level of the human body before it can become really effective. What is the technology level? Since the human body is basically an extremely complex system of interacting molecules (i.e., a molecular machine), the technology required to truly understand and repair the body is molecular machine technology. A natural consequence of [our achieving] this level of technology will be the ability to analyze and repair the human body as completely and effectively as we can repair any conventional machine today."

- Brian Wowk, “Cell Repair Technology”
Nano Biotechnology & Nanomedicine

ANATOMY OF A NANOPROBE

- Acoustic relay attached to an onboard computer sends and receives ultrasound to communicate with medical team
- Pumps remove toxins from the body and dispense drugs
- Outer shell made of strong, chemically inert diamond
- Sensors and manipulators detect illnesses and perform cell-by-cell surgery

WIDTH OF A HUMAN HAIR

Up to 10 trillion nanorobots, each as small as 1/200th the width of a human hair, might be injected at once

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Background

1. Nanomedicine is an interdisciplinary field of science, even a simple project needs contributions from physicists, engineers, material chemists, biologists and end users, such as an orthopedic surgeon.

2. A mature nanomedicine will require the ability to build structures and devices with atomic precision, hence molecular nanotechnology and molecular manufacturing are key enabling technologies for nanomedicine.

3. Nanomedicine must catch up with the technology level of the human body to become really effective. The result will be the ability to analyze and repair the human body as we can repair a conventional machine today.

4. If the nano concept holds together, it could be the groundwork for a new industrial revolution.
History

1. Despite the importance of nanotechnology, literature review of robotics in 1993 included not a single reference to nanotechnology or nanomedicine.

2. The first nanomedical device-design technical paper in 1996 by Freitas: Respirocyte—an Artificial Red Cell.
Example: Respirocytes


Respirocyte pumping station layout. Each station occupies one dodecant (30°) of sphere surface; each respirocyte has 12 pumping stations, any one of which, acting alone, can load or unload a tank in 10 seconds.
Equatorial cutaway view of respirocyte. The oxygen gas chamber is at left (south pole), the carbon dioxide gas chamber is at right (north pole), and the water (ballast) chamber occupies the center, surrounding the onboard computer system. The equatorial bulkhead separates the north and south hemispheres of the device.
Nanomedicine: Big opportunities in a small frontier

Impact

October 26-November 1, 2001

Nanomedicine: promises and challenges

Imagine a tiny sensor molecule that can identify emerging cancer cells inside your body and kill them at their inception. Imagine further that you can drink a cocktail every morning that carries the sensor-killer agent into your gut where it can target early cancers in your colon.

Then calculate the benefits: thousands of lives saved by preventing colon cancer, millions of health care dollars no longer required for its treatment and diagnosis, personal peace of mind for individuals who no longer have to dread the disease or fear the procedures that diagnose it.

This is the promise of nanotechnology—tiny devices, machines or robots constructed from atom-sized components that will be able to diagnose, treat and prevent major illness.

Blocking medicine's progress into the nanoworld are the very laws of nature itself; new laws not fully understood. Systems in the nanoworld involve structures larger than individual atoms but smaller—way smaller—than the cells, microorganisms or biomolecules familiar to biologists. Scientists are finding that nanostructures occupy a borderland between quantum physics and classical mechanics where the old rules don't always apply. As researchers rush to unpack the basic science, engineers are forging ahead to devise practical applications for the newly-discovered principles, thereby creating new technologies.

Brave new nanoworld

How are researchers trying to unravel these complex new laws that will establish the science of nanobiology? Some lessons can be learned from Mother Nature herself by looking at nanoscale biomachines whose workings are well described. A cell, for example, is a complex assembly of nanomachines, including ribosomes, mitochondria and cell membranes. Scientists, learning by example, can model nanotechnologies on such naturally occurring structures.

For example, James Baker, at the University of Michigan, derived inspiration from the ability of viruses to inject DNA into target cells, using instead synthetic polymers called dendrimers to carry out the same function.

Natural structures also lend themselves to use in artificial nanosystems. For example, scientists like USC's Leonard Adelman have learned to use DNA to solve complex computational problems. Certain other molecules, according to Yale's Mark Reed, have the ability to act as an individual "switch," turning current off and on, suggesting that a molecular computer can be built by attaching together a series of such electronically active molecules.

While some scientists are learning about nanobiology by analogy, others are constructing nanomachines from the bottom up, using molecules whose electrical properties allow them to be used as switches and wires. Charles Lieber and his group at Harvard have built nanowires some 20 nanometers in diameter, nanoscale diodes and nanotubes that can act as conductors or semiconductors. These tiny components may ultimately be assembled to form nanoelectronic circuits that can combine massive computational power with subcellular dimensions.

Nanodiagnosis

Conventional techniques for imaging abnormalities and detecting diseases are often cumbersome, expensive, unpleasant or ineffective. Nanotechnology will offer tools to sharpen medical images and make screening tests more sensitive.

• Medical imaging: Nanotechnology replaces present-day contrast agents with minuscule particles that provide more accurate images with fewer side effects. For example, nanoparticles coated with antibodies reacting to a cancer cell and carrying minute amounts of MRI-readable dye can be set loose in the bloodstream and visualized using magnetic resonance imaging when they attach to the tiniest of tumors.

• Testing for other diseases. DNA screening can be done without DNA chips, thus avoiding the time and expense associated with fluorescent tagging and optical instrumentation. Instead, in those diseases where an abnormal protein is produced like prostate-specific antigen in prostate cancer, a micromachine can use an antibody dangling from a cantilever to signal the presence of the protein. As the antibody reacts to the protein, it deflects the cantilever. The slightest deflection can be measured, allowing detection of minute amounts of abnormal protein as the earliest evidence of disease.

Biosensors—convenient and easy-to-use devices—can contain sensitive nanomachines. Whether for confirming ovulation, identifying early pregnancy, testing for chemical warfare agents or warning about biological contamination, nanotechnology-based sensor systems will allow easier, faster and cheaper detection of critical substances.

So, what are some of the other things to watch regarding nanotherapeutics? More effective drug treatment with fewer side effects is one goal of nanotherapy. Nanotechnology can construct "smart drugs" that will know where they should go and how much of themselves they should deploy. In nano-based cancer chemotherapy, antibodies can be bound to nanoparticles containing a chemotherapy drug so that the active agent is released only when the capsule becomes attached by the antibody to its cellular target.

Some attractive targets are the cancer...
Nanostructures in Nature – Some Perspective

1. Nature has created nanostructures for billenia. Biological systems are an existing proof of molecular nanotechnology.

2. The Biology is an ingenious form of nanotechnology, even very simple living cells are able to duplicate. So far there is no machine of any size or type, which could do the same.
Replication

1. Nature Replication is a basic capability for molecular manufacturing. Still some scientists think that medical nanorobots need not ever replicate.

2. Replicators will probably be regulated somehow. One would not want anything that could replicate itself to be turned loose inside your body.
Nanodreams

1. Nanomedicine will (hopefully) eliminate virtually all common diseases, all medical pain and suffering ⇒ theoretically eternal life.

2. Extension of human capabilities.

3. New era of peace. People who are well-fed, well-clothed, well-educated, healthy and happy will have little motivation to make war.

4. Pollution-free industry will guarantee the well-being of nature.
**Nanohorrors**

1. Self replicating nanorobots could become massive chemical and biological weapons.

2. Changes to human properties, such as brains, respiration, muscles and DNA will be uncontrolled and may threat the existence of human being.
Potential Application of Nanomedicine

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Human Targets

Nanotech data storage memory system
Increased frequency range, parabolic hearing
In vivo fiberoptic communications backbone
Internal wholebody navigational grid

Metabrain

Error correction device - instant data replay and feedback
Network sonar sensors map data onto visual field
Cardio flow and function monitor
Biosensors externally stimulate atmospheric tensions

Solar protected skin with tone - texture changeability
Turbocharged suspension flexibility
Replacement organs

OPEN 24 HOURS

Primo 3M+
a product of Ageless 2001
Imagine an army of tiny robots, each no bigger than a bacterium, swimming through your bloodstream. One platoon takes continuous readings of blood pressure in different parts of your body; another monitors cholesterol; still others measure blood sugar, hormone levels, incipient arterial blockages and immune-system activity.
**Drug Delivery**

1. Nanoparticles may deliver drugs in sophisticated ways, like target-specific and trigger-based drug dose. Target specific delivery may enable the use of lower doses, because the whole body will not be saturated with the drug. Side effects may be minimized, and it may be possible to use stronger drugs, which cannot be used by conventional drug delivery.

2. The use of particles in cancer healing is an example of target-specific action. Gold plated spheres will be linked to tumor cells. The nanoshells will be heated from the outside with an infrared source. Heating the shells will destroy the cancerous cells, leaving the surrounding tissue unharmed. (maybe???)
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Drug Delivery - Example

Insulin-dosing is an example of trigger based drug delivery. Insulin therapy for diabetes requires a low baseline release of the drug with peaks after the ingestion of food.
Improved imaging with better contrast agents may help to diagnose diseases more sensitively. The method may enable the detection of very small tumors and other organisms which cause disease.
Tooth Cleaning Robots

Teeth cleaning robots collect harmful bacteria from the mouth. (The robots are magnified x1000)
Similar cleaning robots can be used in lungs. We have natural macrophages in alveoli, but they are not able to metabolize foreign particles like fibers of asbestos and toxic effects of smoking from the lungs.
Artery Cleaning Robots

Extra fat can be removed from the arteries with cleaning robots. Mobile nanorobotic janitors (green) patrol the lungs, collecting inhaled debris and transporting it to recycling stations (blue-gray).
Improving the Memory

A nanostructured data storage system may store a nanocomputer and an amount of information equivalent to an entire library. The spheres are in contact with the brain cells.
The Properties of Medical Nanodevices

- Shape and size
- Biocompatibility
- Powering
- Communication
- Navigation
More realistic....
DNA Detection

Hybridization of a known “bad” sequence with a complementary strand from the tested blood enables to identify diseases.
DNA Microarrays Chips

Hybridization of a known sequence with a complementary strand from the tested blood followed by fluorescence detection.
The DNA unfolds upon potential difference application and forwards according to length.
Detection Using Cantilever

Magnetic field exerts force on bead
Antibody-coated magnetic bead
Analyte
Cantilever
Electromagnetic coils

The resonance frequency changes upon molecular binding.
Meanwhile .... We need to work hard! .... and Be Patient....
Course Summary
Nano Motifs

1. The miniaturization raises new dominant properties and mechanisms due to atomic and molecular dimensions (quantum size effects).

2. Accurate “topographic” and structural constructions (nanostructures).

3. Interdisciplinarity.


5. Combination of bottom-up with top-down.
Nano Tools

1. Inspection (++) – SEM, TEM.

2. Inspection and spectroscopy (++) – SPM (STM, AFM, Etc.)

3. Patterning and construction – Lithography (Optical, e-beam), SAM.

4. Molecular synthesis and surface coverage.

5. Theory – single charge phenomena (e.g. SET).
Nano Directions

1. Nanoelectronics and Nanocomputation.
2. Nanomechanics and Nanoengineering.
3. Nano bio(techno)logy and nanomedicine.
4. Nanochemistry
Good Luck
and....
I hope you enjoyed!!!