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BIOMEDICAL ENGINEERING AND PUBLIC HEALTH

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It is a special pleasure for me to be with you today at this inaugural session of your new institute for medical and biological engineering. My surprise was in learning that this was an inaugural session. You will understand my surprise when you appreciate that I spent the last 14 years at Johns Hopkins where Dr. Dick Johns has been such a visible and eloquent proponent of biomedical engineering -- especially within the Council of Deans. My assumption was that the rest of the medical world had to be similarly populated with professionals in this field -- and, as an inevitable corollary, that there would be a number of professional associations such as this. Whatever, do rest assured that I, at least, have been thoroughly educated (indoctrinated) as to the potential of biomedical engineering.

During the past decade, as you know well, we have been witness to a transformation in medical science what with an exponentially growing appreciation of how individual cells and components of cells respond and change in response to chemical and physical agents. Biotechnology has emerged, offering the potential to change and improve every facet of our existence from the food we eat and the water we drink to the energy that fuels our machines and the materials from which they are constructed. When coupled with new developments in bioengineering, we are confronted with an array of possible scenarios which challenge us to dream the previously unimaginable -- with reasonable expectations that our goals may be achieved.

The Bush Administration is deeply committed to the development of America's foundations in basic science and to their practical application. Dr. Bromley spoke with you about new Administration initiatives this morning and Secretary Sullivan about prevention just a few moments ago. (I am not sure there is much left for me to say.) Of special relevance to your own field is the new national Biotechnology Research Initiative, extending across 12 agencies, and with a budget of over $4 billion. Its goal is to sustain U.S. leadership in biotechnology research and to extend its commercial potential. It is but one of five Presidential Research Initiatives intended to strengthen research in American and its commercialization into the 21st century. Certainly, it has wide applicability to biomedical engineering.

The quandary for all of us today is that of selecting the most productive research directions to pursue as there are now so many potential avenues. In medicine, the emphasis until recently has primarily been on diagnostic, therapeutic and remedial modalities with rather little thought given as to the potential cost of new developments. But times have changed. I recall, once, not all that long ago -- when I was a resident -- we truly utilized every diagnostic, therapeutic and remedial measure available with every patient and without regard to cost. To a degree we still do. However, just 30 years ago, our armamentarium was so limited that there was little reason to question the costs of what we did. That is not true today, as well you know. Increasingly, questions are raised, as well they should be, as to whether new and improved preventive measures might not receive far greater emphasis than they have -- whether perhaps we should invest less heavily in Lew Thomas' half-way technologies and whether there might not be better methods for the delivery of health care itself.

These new considerations carry a special onus both for public health and for biomedical engineering.

At first blush, the two fields seem poles apart. Public health, as its name implies, focuses on the health status of entire populations; whereas biomedical engineering customarily focuses on individual patients in the traditional curative and remedial care relationship. Public health emphasizes the prevention of disease and disability, whereas, to date, biomedical engineering has manifested the diagnostic, therapeutic and remedial orientation of its medical collaborators. Public health promotes vaccination and other preventive and health-maintenance services, safe environments for the home and workplace and healthy life-styles, whereas biomedical engineering, through the development of devices and through other applications of concepts from the physical sciences and mathematics, has focussed primarily on individuals who already are disabled or ill.

We do share an interest in viruses, however. Of course, for those of us in public health, our viruses are made of nucleic acids and proteins; and they infect cells. Yours are made of bits and bytes; and they infect computers. I must admit that your discipline seem to be doing much better than ours in rooting out viruses after infection has occurred; but we have the edge in developing vaccines. Perhaps we have something to learn from each other after all!

Although I exaggerate the contrast between public health and biomedical engineering for rhetorical purposes, I believe my comparative characterization nevertheless is close to the mark. The differences between the two disciplines traditionally have outnumbered the similarities by a wide margin.

I wonder if this might not reflect the fact that, to date, biomedical engineering has remained largely embedded in the curative care environment of the medical setting. As we know, one's research agenda is inevitably driven by the questions and problems posed by the research milieu and by professional colleagues, and this is as true for applications in biomedical engineering as in the clinical specialties. Unfortunately, few of those immediately concerned with today's major public health problems are to be found within the medical school setting. Thus, fundamental questions relating to such as immunization, risks of toxic environmental exposures or disease surveillance are unlikely to appear on your agenda.

Let me offer one primitive illustration of what I mean. One object in common use today is the needle and syringe -- a comparatively primitive instrument, little changed or improved over recent decades. For parenteral administration for individual patients, it may well be the simplest and best device but for the public health practitioner, endeavoring to administer hundreds of vaccinations per day, it is unbelievably cumbersome and nothing more nor less than the limiting factor in an immunization program. Yet, we know that injection by high powered jet spray is a perfectly feasible approach for administering vaccines. The U.S. Army demonstrated this 30 years ago. However, the only injectors available for use today are the costly, bulky instruments all too prone to breakdown which were introduced a generation ago. Could they be improved? Is it possible to conceive a simple instrument with few moving parts costing perhaps $25 to $50 instead of $2000? The answer is yes. A prototype is at least being fabricated but only after nearly two decades of all but total disinterest on the part of the engineering community.

In public health, the parameters are defined in terms of simple, less costly and user friendly. We need to seek opportunities to work more closely together in the future.

Let me offer an example of another possible challenge, an idea for which I am indebted to my colleague, Dr. Bill Raub. Imagine a small, battery-powered gadget about the size and shape of, say, a silver dollar that, when attached to a conventional phlebotomy syringe, performs a differential white-blood-cell count or detects a chemical agent, on the spot and in a matter of minutes. Such a device could have wide applications by epidemiologists and in physicians' offices, store-front clinics, and other health-care settings in both industrialized and developing nations. Equipped with a solar panel to meet its energy needs, the compact cell counter also could find ready use in field studies.

Could we realistically expect to develop such a device? Maybe so; maybe not. But one thing is clear: we will not know unless health professionals and engineers receive encouragement and resources to collaborate in assessing the feasibility of such ideas, especially when promising leads exist.

In this instance we already have a promising lead -- namely, the technology of micromachines. In using the term "micromachines," I am referring to mechanical objects less than a millimeter in size, with components having a magnitude of about 100 microns or smaller. Like their macroscopic counterparts, micromachines can be designed to rotate, cut, pinch, slide, pivot or whatever. Their diminutive dimensions make possible a wide array of options for engineers to incorporate them into other machines such as automobiles, robotic manufacturing systems, scientific instruments and medical devices.

Many of you are familiar with the concept of micromachines but for those of you who are not, let me take a few minutes to highlight their technological background. The potential importance of micromachines stems not only from their size but also from the way they are made. The technology is essentially the same as is used to make silicon microchips for computers. That is, each specific design for a machine is translated into a succession of computer-controlled etches and depositions on the surface of silicon wafers to produce one or more entities of the desired size, configuration and operating characteristics. A special step in the construction of micromachines is the use of sacrificial materials to stabilize effector elements such as rotors or cantilevers while fabrication of the device proceeds. At or near the end of the process, the restraining materials are dissolved by immersing the entire wafer in an acid bath, thereby freeing the microscopic effectors to move as intended. All this is a far cry from the component-by-component assembly that characterizes conventional machinery.

This mode of manufacture results in several important advantages. First, being based on silicon-microcircuit technology, micromachines can be made in the facilities that produce computer chips. Second, although the manufacturing plants are costly, the raw materials for the devices are not; the finished products, therefore, are likely to be inexpensive -- even to the point of being one-use/throw-away instruments. Third, chemical sensors can be incorporated by layering films of selected enzymes onto the appropriate surfaces within the micromachines; miniature mechanical sensors such as pressure transducers already have been developed with silicon-wafer technology. Fourth, hundreds of copies of a given device could be created on a single wafer, generating a tremendous economy of scale for commercial production if the product proved successful in meeting a health need. Fifth, because micromechanics are based on microelectronics, the fabrication of the circuitry to control the moving parts could be integrated fully with the fabrication of the machine itself.

The last two advantages reinforce each other in a dramatic way. The ability to make many copies of the same device and set them out in neat arrays creates the opportunity to exploit parallel operations to achieve efficiency. The ability to integrate the electronic components with the mechanical ones means that the control circuits needed to effect the parallelism can be an integral part of the device. For many applications, a complex array of hundreds of simple machines working in a highly coordinated way may prove far superior to a single machine made of many heterogeneous parts.

Let me return to such as the hypothetical lymphocyte-counter which, in fact, represents a surrogate for other devices designed to measure any of a number of chemical substances. One could envision its core as a single silicon chip containing hundreds of miniature gating devices, each designed to send white blood cells into one channel and all the other blood elements into another. As the lymphocytes pass single-file through the parallel gates and are illuminated by light from an associated fiberoptic element, an array of microsensors might detect the characteristic spectral signatures of the different types of white cells and tally them accordingly. All this parallel processing would be controlled, of course, by electronics etched into the machinery; and, because the electronics contain a basic instruction set and externally accessible memory, the micromachine could be programmed to operate on the cell counts with whatever logical operations the users might specify.

Dreaming is fine, but doing is what counts at the end of the day. Therefore, the question is "Could such a device be built?" "Could something like this be adapted to detect and measure chemical substances?" Or, if you will grant me the assumption that all the requisite technology exists in principle, the better question is "How might we go about determining whether such a device is feasible and practical?"

The general answer is easy to verbalize; the need is to foster sustained collaboration among health professionals, medical scientists, biomedical engineers and others who can help shape the applications of micromechanics in the health area. This means welcoming (indeed, inviting) initiatives from appropriate groups within the scientific community, subjecting their proposals to peer review and funding the best ideas for up to 5 years at a time. This also means helping academically-based innovators establish effective working relationships with relevant industrial organizations -- both those who now manufacture silicon microelectronics and those who might undertake the commercialization of medically relevant micromachines.

I offer these illustrations only to suggest that there is a vast field of public health applications which would benefit greatly from the creative imagination of biomedical engineers.

Let me conclude with the hope that future sessions of your Institute might highlight this need with one or more sessions dedicated to "Biopublic Health Engineering."