The Sci-Fi Future of Medicine … the Next 50 Years

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INTRODUCTION

Ancient medicine was often based on magic, rituals, and misconceptions, but also on the chemistry of nature. The ancients discovered herbs, teas, and other medicinal agents that helped cure many, but not all maladies. Chinese teas, African herbs, and other natural remedies, have been shown to contain useful drugs. In fact, modern pharmaceutical firms still extract materials that are not easily synthesized. Turn on your TV and be blitzed with ads selling better health through chemistry! But electronics, photonics, micro-mechanics, and other technologies have been steadily moving into the medical realm. The first noteworthy application of medical electronics goes back to the 19th century – Roentgen Rays, better known as x-rays. The X-ray machine has evolved into the modern 3D CAT-scan and early “electro” cures have been replaced by a myriad of useful medical gadgets.Today, we’re just at the beginning of sci-fi like medical technology, where “pill cameras” may replace x-rays and all kinds of implants, including new incredibly small blood-pressure sensors, are saving lives. But in the future, implanted monitors/drug dispensers will normalize the lives of diabetics, the doctor will again make house using telemedicine, and body-roving medi-bots will repair the body and help maintain our health. During the next 50 years, medicine will focus more and more on electronics and emerging technologies, including MEMS (Micro-Electro-Mechanical Systems) and Nanotechnology, while also embracing customized pharmacopoeia. There will also be a convergence of technologies where advanced electronics, micro mechanic, and nanotechnology will merge using breakthroughs like pharmacy-on-a-chip and implanted “body regulators”.

BACKGROUND

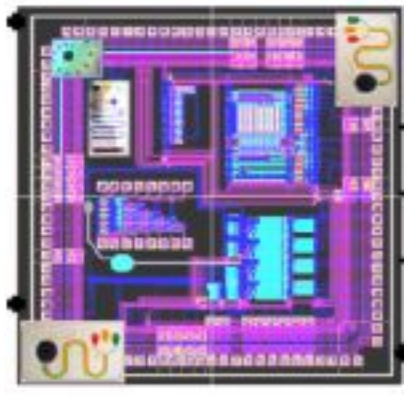
Remarkable advancements in medicine are increasingly accomplished through the innovative application of electronics, photonics, micro-mechanics, and related emerging technologies. Long-range preventive medicine and early preemptive intervention are becoming essential strategies to more cost- effective and life-prolonging health maintenance made practical through continuing advances in diagnostics and wellness assessment enabled by leading-edge technology from over a dozen fields. Early medicine emphasized external examination of the patient. Later, breakthroughs beginning with x-rays, permitted internal examination from the outside. But future medicine will examine the patient from the inside out. While electronics, photonics and micro-mechanics, and their combinations, have enhanced external diagnostics, new principles and extreme miniaturization will permit examination, sensing, monitoring, regulation, and treatment from inside the patient. Concurrent breakthroughs in molecular biology and a better understanding of the coding and functions of DNA, is building up a knowledge base that will make diagnostics even more powerful and allow deployment of preventive and interceptive medical techniques at an earlier stage for greater success. Gene-based medicine may be the ultimate frontier, but micro-mechanics will progress faster.

One of the most important newer technologies is MEMS that can combine digital and analog electronics,with movable structures, all on a single chip. Now add light for optical-MEMS (aka; MOEMS; “O” =opto) and we now the most versatile technology suite available since all the sciences can now converge onto and into a tiny implantable chip that will bring a revolution in medicine. This emerging field is called Bio-MEMS.

Bio-MEMS – Fab the Med-World on a Chip

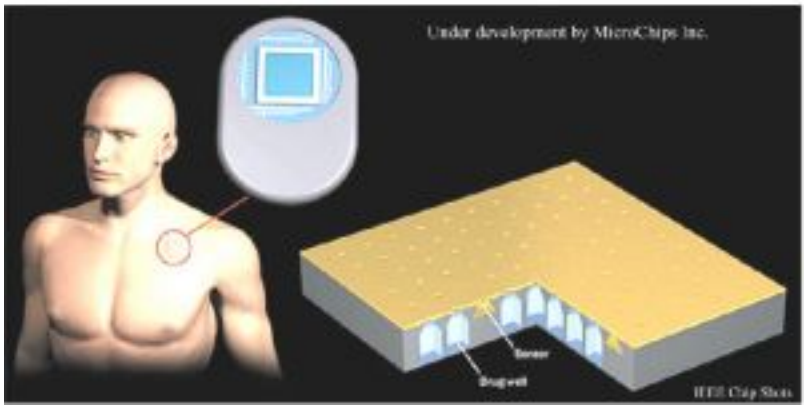
MEMS has been saving lives for more than a decade as the critical chip in the vehicle air bag sensor; MEMS accelerometers sense a crash as abrupt deceleration, and instantly send electrical signals that “fire” air bags. MEMS adds mechanics to electronic chips to accomplish an endless array of tasks at the micro-level. Emerging Bio-MEMS technology will construct pumps, filters, drug injectors, toxin detectors, and all kinds of sensors that measure everything from pressure to blood chemistry. Miniature blood pressure chips will be threaded into a vein or artery to report data using wireless telemetry. Bio-MEMS analyzers will even amplify DNA and provide complete decoding by the year 2025. By 2035, MEMS and other chips,

will supply complete DNA decoding data, to a powerful Nanoelectronic computer that will identify hereditary problems that will be corrected by personalized medicine synthesized in minutes by pharmacy-on-a-chip technology.

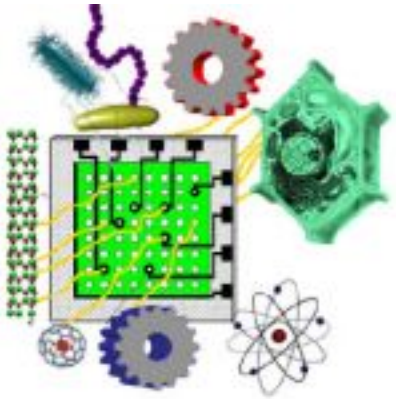


MEMS fabrication can create 3-dimensional structures out of silicon,with many of the same processes used to make computer chips. The ability to create channels, chambers, controllers, and essentially every type of part from the macro-world, means that we can build a factory in a tiny chip. Fluidic-MEMS chips can be designed with micro plumbing to handle gases, liquids and even nano-solids. A chip will be made to

mimic a pharmaceutical plant, even a complex one. By 2045, we will be able to synthesize gene-specific drugs that will treat specific ailments even if the malady only affects one person on the planet. While we wait for patient-specific drugs, auto-monitoring self-regulating drug dispensers can use commercial pharmaceuticals. These drug dispensers, that will begin use in 2016, will use fluidic-MEMS technology to inject on demand. Lab-on-a-Chip (shown right) will allow small amounts of bodily fluids to be tested in seconds. The biochemical reactions will occur inside the biochip's chambers and channels that are fitted with micro-valves, pumps, and heate



rs. Even a drop of blood, that typically does not contain enough DNA for analysis, will be amplified (multiplied) using the polymerase chain reaction (PCR) and then analyzed – in minutes, not days. The entire modern medical lab will be effectively reduced to a chip – one that can be mass-produced making it suitable for any point-of-care, even the home. Biochips will also treat the patient. Wearable and even implanted body monitor/drug dispensers will become increasingly common. The system will continually monitor blood chemistry and dispense the appropriate drug from a store of about 100. Pathogens will also be monitored and MEMS pumps will inject appropriate antibodies from a library of treatments.



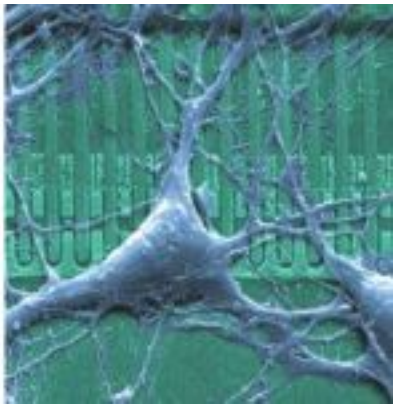
Adoption of Bio-MEMS technology will enable us to advance medical diagnostics and therapies by greatly reducing device size and cost, because of wafer-level fabrication, while increasing capabilities. Future applications will be unlimited, but the most common will include drug delivery systems, portable ultrasound imagers, skin cancer detectors, and advanced implanted monitors with telemetry. Newer techniques, like magnetic flow cell sorting will have various diagnostic and therapeutic applications, such as rapid

screening for cancer cells in blood. Bio- MEMS capabilities will rapidly increase and diversify in the future to become one of the most important medical technologies of the 21st century.

Tele-Doctor Makes Home Visits

But even future preemptive medicine won't solve every problem. And the health care professionals will be there to help – instantaneously. Check-ups and most evaluations will involve telemedicine that is already in limited use today. Vital signs will be transmitted to the care center using Internet, mobile phone service, or other wireless modes that will cover most of the world in the next 10-years. While some may have an assortment of medical interface modules at home, cyber clinics will have the resources equal to today's university hospitals. Even biopsies, and minor surgery, performed by robots, will be available at cyber-meds. And those with life-threatening illnesses can live at home guarded by implanted wireless monitor systems. Data, signaling an emergency, will be transmitted to the health care center that will send help, alert others, and help stabilize the patient by monitoring and re-programming the on-board (in vitro) computer. The monitors and controllers will be so powerful, that a response can be made for nearly any situation. Even an injury will be dealt with via remote control while help was on the way.

Electropharma – Turn on the Good Times



A new breed of bioelectronics will play an increasing role in the future as we learn to modify body chemistry without external drugs. Electro-bio-chemistry will do everything from promoting tissue re-growth, including organ regeneration, to stimulating natural antibody synthesis. By 2025, we will eliminate pain, fall asleep in seconds, improve eyesight, and even get cheered up using bio-electronic devices that interact with body and mind. Some devices will stimulate production of natural agents. The Sleep Inducer will cause the body to produce just the right amount of melatonin for falling asleep. Time to wake up? No need for an alarm clock since the Sleep Inducer lowers melatonin for wakefulness at a preset time and maybe adds a little adrenaline as the second wake-up call. The body is capable of producing thousands of agents and we will learn how to turn them "on" and "off" for better living through Electropharma.

Replacement Parts by Mail Order?

Even the best body parts can break and wear out, so future medicine will create a “parts store”. EBay will legalize transactions in body parts since all will be manufactured. We already have artificial hearts, but in the future, most organs will be manufactured; eyes, kidneys, livers, and much more. Even today, simple retinal replacements are in development, but by 2040, sight will be restored using a variety of options depending on the problem. A photo-electronic implantable retina will connect directly to the optic nerve. In some cases, a complete “bionic eye” may be required that will interface directly with the brain. But by 2050, bio-science will deliver “harvested” eyes that will ultimately replace “constructed” substitutes. We’ll learn to grow most organs at “body farms”. The kidney, the most replaced organ today, will first be manufactured as an inorganic composition using Nanotechnology that is ideal for making selective filters. Later, a biological hybrid kidney will succeed. But at the final frontier, the kidney will be organically grown in sufficient quantity to satisfy all in need. Advanced monitoring and genetic adjustments will reduce the number needing transplants, however. We will also utilize in situ organ regeneration before resorting to replacements. Several methods for regeneration will be available; implanted stem cell-derived tissue, biochemical-induced growth, and bio-electronics stimulation. Sex change and designer gene boosts will be simple.

Invasion of the Body-Bots

Preventive medicine and wellness maintenance will be the theme of future medicine; fix it before a natural programmed break occurs. We will know what will “break” decades before anything happens, thanks to gene decoding by Blue Gene styled medical laptops. Body “re-programming” will be popular, as will baby mods. Gene swapping, while frowned upon, will be a big business. But not everyone will opt for “messing with nature” and not every medical problem will be understood, even in 2056. While some will shun anything that is radical, most will opt for diagnostic/monitor implants. So, we’ll still need medical help from time to time. Personal robots, ranging from life mates to care givers, will be common. But while standard household robots may pick up on your health problem, many will want to go the medi-bot route. Ironically, personalized medicine will not be delivered by people.

We’ll use implants to diagnose the earliest abnormalities and help plan more suitable and successful strategies. A chip will alert us to potentially cancerous tissues. Bio-MEMS chips equipped with sensors will detect mutated genes or dangerous levels of hormones, and even pinpoint which tissues to treat long before the situation goes critical. Mobile monitors will eventually replace stationary implants, and will be much more useful. The concept of a personal

“internal medico” will become widely accepted, if not popular. MEMS-enabled micro-robots, or even “nanobots”, will travel through the body to clear arteries and make repairs, like in a scene borrowed from the classic 1966 science fiction movie “Fantastic Voyage”. The movie plot used miniaturization technology to enter the patient’s body with a guided fluid-impervious vehicle to clear a blood clot. Although the science fiction plot was based on atomic- level miniaturization of a macro-world submarine, the even smaller autonomous Bio-MEMS vehicle will be used in the future. These self-guided and self-propelled devices will be injected into the body by syringe. They’ll be on patrol, looking for problems and doing routine body maintenance, and even perform life-saving tasks. You may not realize that your life has been saved until you query your bots for a status update. These medi-bots will be the next “big” small thing bringing new meaning to internal medicine. Small enough to be injected into the blood stream, the self-propelled submarine-like devices will navigate the tributaries of your body seeking out restrictive plaque and everything that is a health hazard. Equipped with micro-surgical tools and nano-lasers, the bots will keep your “plumbing” clear. The combination of lesion-sealing surgi-bots and gene repair drugs has eliminated most of the terminal diseases including HIV, cancer and Alzheimer’s. The good news is that the bots keep on trucking – swimming. No batteries are needed since these tiny silicon machines derive power from blood-borne nutrients – just like your muscle.

But just how long will the bots last? Most will run for at least 100 years and the large number per individual means that there is considerable redundancy. While there will be hardware upgrades every few years, software updates will suffice for decades. Automatic wireless software updates will even inoculate you against the next “bug” (yes, the flu is still around) making flu shots obsolete. The roving antibody stimulator bots will “set” your immunity every year. But even in 2056, we still have a few problems carried over from 2006. Your bio-virus checking medi-bot army can still catch a software virus. Worse yet, you can really get sick if your bots need to be rebooted, or they turn malignant. But diligent security efforts are thwarting most terrorist “bot bomb” attacks.