The Invasion of Modern Medicine by Science Fiction
or
The Search for the Fountain of Youth

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The allure of science fiction, like beauty, is in the eyes of the beholder. Yet a glimpse beneath the surface of good science fiction is often a glimpse into the future of scientific discovery.

Like many fields of science, the future of medicine is frequently predicted by the science fiction writers of today. And while it's fascinating to speculate about what the future of medical science will bring, it is perhaps even more interesting to look back and see how today's medical marvels may have been influenced by yesterday's dreamers.

Many of today's medical advances were presaged by science fiction stories of the past. Is this because those writers had an uncanny ability to predict the future, or was it because they had a gift for stimulating the imagination of the children who would dare to become the future generations of scientists to make those dreams come true? Most likely, reality lies somewhere in between, but either way it's hard to argue the importance of the vision of the most gifted science fiction writers; authors like Mary Shelley, Jules Verne, Arthur C. Clark, Isaac Asimov, and Gene Roddenberry to name too few, have influenced generations of brilliant scientists who have shaped our present and are in the process of shaping our future.

It is, at best, difficult to trace the roots of invention, the seeds that sow the original ideas that lead to the most important changes in our understanding of the universe. Inventions rarely occur in one giant leap, but rather tend to occur in a series of steps, each painstaking advance built upon the work of those who came before, until the final step, the breakthrough that leads to a fundamental change in our understanding of the universe that surrounds us. The sapling born from the first seed of invention is long gone by the time the tree bears fruit. The scientist credited with the ultimate breakthrough is often unaware of the motivations of the scientists who came before, those who laid the foundation for the work. Therefore, we can only guess at the motivation for the idea's originator in many circumstances.

With that in mind, let's take a look at the influence of science fiction from the nineteenth and twentieth century on modern medicine in the twenty-first century. This is certainly not an exhaustive compilation, but merely a deep enough glimpse to make one wonder whether yesterday's writers were great visionaries or merely great motivators.

Transplant Surgery

In 1818, Mary Shelly stunned the world with what many consider the first true science fiction book, and what most would agree was the first story to bring science fiction to the masses – *Frankenstein, or the Modern Prometheus*.

When Shelley wrote *Frankenstein*, it was surely meant to be more of a political statement than a science fiction story, but the idea of transplanting body parts to create new life certainly stirred the imagination of readers for generations to come. Although the reanimation of dead tissue remains the realm of the sci-fi/horror genre, the techniques of transplanting tissue from a deceased donor to save the life of another human being is now in the mainstream of modern medicine.

To what extent Shelley's writing spurred the interest of future surgeons is unclear, but in 1905, the first successful tissue transplant surgery in a human being took place, and by the 1930's, the first deceased-donor organ transplant was attempted (coincidentally?) just two years after the release of the movie *Frankenstein*, starring Boris Karloff.

Tissue rejection remained the main obstacle to successful transplants into the 1970's, when new immunosuppressive medications became available and brought transplant surgery into the mainstream. People began to accept the marvels of kidney and even heart transplants, but as is often the case in science fiction, a potential sinister abuse of the new technology was dramatized in the 1977 book *Coma*, by Robin Cook, in which hospitalized patients were mysteriously lapsing into irreversible comas in the operating room, thanks to the efforts of some nefarious entrepreneurs who hoped to harvest their organs for great profit. The movie of the same name was released in 1978 to great commercial success.

Another movie, *Face-Off*, starring Nicholas Cage and John Travolta, explored the potential abuse of a new kind of transplant surgery – face transplants; in this film, an FBI agent assumes the identity of an imprisoned terrorist by undergoing an experimental operation – having the terrorist's face transplanted onto himself, in an effort to uncover the plans for a suspected nuclear attack. The plot thickens as the faceless terrorist awakens and overpowers his captors, forcing them to make him the recipient of the FBI agent's face. The hunter becomes the hunted as they assume each others identities, even their closest friends and family unaware of their game.

Hauntingly, it was less than a decade after the fantastically fictional plot of this 1997 film was written when the first real facial transplant was performed. In reality, this revolutionary and highly publicized procedure performed in France in 2005, does not actually give the recipient the facial appearance of the donor; it does however offer a major breakthrough in the treatment of facial deformities.

Several science fiction authors have explored the ultimate organ transplant, including Lee Cronin, who wrote the *Star Trek* episode *Spock's Brain* in 1968, in which the brilliant Vulcan's brain is stolen by aliens who need it to run the supercomputer that maintains their civilization. The story raised the ethical question of stealing an organ, even when it's used for the greater good. A very different set of ethics was addressed in 1970 by Robert Heinlein in *I Will Fear No Evil*, when an old man has his brain transplanted from his dying body into the oversexed body of his young secretary, who had just perished in a motor vehicle accident. And now in the twenty-first century, remarkably, brain transplants…no, we're not even close.

Non-Invasive Surgery

In the 1984 movie *Star Trek IV: The Voyage Home*, the crew goes back in time to 1980's San Francisco. Commander Chekov (Walter Koenig) is attacked, and is rushed to surgery with an expanding epidural hematoma (a pool of blood between the skull and the brain). Just as the neurosurgeon is about to make the first cut, Kirk (William Shatner) rushes into the room with Dr. McCoy (Deforest Kelly), who confronts the surgeon. "My God, man," McCoy exclaims, "drilling holes in his head is not the answer. The artery must be repaired. Now put away you butcher knives and let me save this patient before it's too late." McCoy's reaction was the equivalent of how today's doctor would react if he were to travel back in time two hundred years and see a patient being treated with bloodletting to relieve congestive heart failure.

Although we're still a long way from the technology that Dr. McCoy had at his disposal in *Star Trek*, today's surgeons now have the capability to perform procedures that seemed just as far-fetched only a couple of decades ago. The most widely known is the Gamma Knife, which allows the neurosurgeon to focus X-Ray beams directly onto a tumor in the middle of the brain and kill the malignant tissue without ever making a cut. Treatment that once required slicing through the brain can now be accomplished with an invisible beam that leaves healthy tissue untouched, following which the patient can walk away from the treatment room just as Commander Chekov walked out of that operating room minutes after Dr. McCoy worked his magic.

With the success of the Gamma Knife, a similar treatment apparatus was designed to locate and treat tumors anywhere in the body. The CyberKnife, like the Gamma Knife, works by focusing hundreds of beams of radiation onto the tumor with pinpoint accuracy. The tumor is destroyed while sparing the surrounding tissue.

Maybe even more remarkable are the advances of endovascular surgery which have occurred over the past decade. Blocked and malformed arteries, which once required potentially dangerous invasive surgery, can now be repaired by highly trained vascular interventionalists, physicians who wield a catheter with remarkable dexterity. A fine-bore tube is inserted through one of the large arteries in the groin, and carefully guided inside the body as the doctor monitors its progress through fluoroscopy (a real-time enhanced X-ray that is viewed on a television monitor), watching as the tiny catheter makes its way up through the inside of the arteries into the limbs, heart or even the brain. The physician can then manipulate tiny instruments through the catheter to clean out blood clots, place stents (tubes that hold the arteries open), or inject tiny platinum wires into an aneurysm, which coil up as they are released, filling the aneurysm with inert metal so it can never bleed again.

As technology marches on, the possibilities of less invasive, more effective means of correcting abnormalities within the human body will continue to increase. Early twenty-first century surgery will be viewed by future generations of doctors with the same reaction Dr. McCoy had when viewing a state-of-the-art 1980's operating room: "We're dealing with Medievalism here."

Robotics

Perhaps creating the quintessential image of modern science fiction, Isaac Asimov gave form to imagination with his depiction of Robbie the robot in the short story *A Strange Playfellow*, in 1940. Not only did he bring to life the physical form of an artificial intelligence being, but more importantly, in his later writings he defined the basic principles on which many subsequent books about robotics would be founded: the three laws of robotics. These laws defined how robots would interact with humanity while, even with their superior strength and intelligence, they would never be a threat to humanity. In defining the basic make-up of a robot, Asimov allowed his readers to embrace the concept of artificial intelligence instead of fearing it.

Our fascination with robotics dates back to a time long before Asimov popularized the term. As far back as circa 350 BC, a Greek mathematician named Archytus of Tarentum built a steam-propelled mechanical pigeon. Although the scientific limitations of the day limited the rate of technological development, the idea of mechanical creatures persisted, and in 1495 the ever-prescient Leonardo DaVinci built an armored knight that could move as if there was a real person inside of the suit.

Mechanical automatons remained popular through the centuries, but it was not until Czech author Karel Capek's 1921 play, entitled *Rossum's Universal Robots*, that the term 'robot,' derived from the Czech word 'robota,' meaning compulsory labor, became a part of our culture. Five years later, the movie *Metropolis* introduced robots to movie goers around the world.

But it was the great Isaac Asimov who is largely credited with bringing the terms 'robot' and 'robotics' into the mainstream of the literary world, starting with his first robot story in 1940, and widely popularized in his compilation of short stories in 1950 entitled *I, Robot*. It was here that the seeds were sown that would forever alter the way we interact with our environment, for with the dawning of the computer age the synergy of automated machines with artificial intelligence would become reality. Future generations of scientists who were raised on the imaginings of Asimov were determined to make their dreams come true.

By 1956, the term "artificial intelligence" was introduced into our culture, as the Dartmouth Summer Research Project on Artificial Intelligence accelerated the transition of robotics from the realm of science fiction to the reality of hard-core science. The advances in entertainment and industry that followed over the next half-century have been widely touted. These days, no one thinks twice about working with an interactive computer, or seeing robotic arms in an automotive assembly plant. The utilization of robotics in medicine is less mature, and therefore less well known, but the changes underway will result in a revolution in the way health care is provided.

Although humanoid robots only exist in our imaginings of the future, modern medicine has already started to reap the benefits of robotics research. Computerized machines with robotic arms and tools allow surgeons to operate through tiny openings, minimizing tissue damage. Other robots will allow surgeons to operate on patients in isolated areas; a surgeon with a particular skill may not be available in a rural town, but a robotic surgeon can be set up in that small town hospital, where it can be remotely controlled by a surgeon many miles away. This is not a mere whim of science fiction, but is already reality. On September 7, 2001 a doctor in New York performed gallbladder surgery on a patient in Strasbourg, France, using a computer and an internet connection to manipulate a robot on the other side of the Atlantic. Though not in widespread use, this technique holds the promise of allowing surgery not only in rural areas, but even aboard ships – on the ocean, in outer space, perhaps even on the first Mars colony. Emergency medical care will be within reach even when the doctor is not in.

Another blossoming example of robotic engineering breaching the bounds of traditional medicine is in the rehabilitation of people who have suffered strokes or impairment of their limbs from other neurological conditions. In this case, a robotic piece of equipment can refine the therapy regimen to aid in the recovery of lost muscle function. Where further recovery was long thought to be an impossibility, robots now offer a new ray of hope.

In recent years, we have learned that the brain possesses a property referred to as plasticity; that is, the brain can learn to utilize new areas to recover lost function. New imaging techniques such as PET (Positron Emission Tomography) scans and functional MRI (Magnetic Resonance Imaging) allow us to see which areas of the brain are active during certain activities. We now know that new areas of the brain can be activated after the primary area that controls a specific function is damaged.

Several robots have been designed to help augment this phenomenon, one example being the MIT Manus. MIT has long been known as a center of innovation, and in 1961, a computer-controlled mechanical hand was developed by MIT researcher Heinrich Ernst. This helped found the basis for industrial robots, but the incorporation of robotics for medical treatment has proven to be more difficult, and would not be perfected until later in the century. In the late 1980's, another MIT researcher, Hermano Igo Krebs, incorporated his knowledge of robotics into the development of a human-machine interface, designed to help stroke victims regain the use of their arms with the help of his robot, the MIT Manus. After years of research to perfect the robot, it has proven to be an effective tool in promoting recovery after stroke.

Bionics

In 1974, the word bionic became a part of the American pop culture, thanks to the introduction of a new TV hero, Steve Austin, *The Six Million Dollar Man*. The show appealed to action fans and sci-fi fans alike. 'Bionic' is actually an amalgam of the words biology and electronic, and refers to using what we know about how things work in nature to build replacement parts for those things. The goal is to be able to replace a defective body part by manufacturing an electro-mechanical duplicate version of that part. In theory, we should be able to exactly reproduce the function of any body part with artificial components that won't age and wear out as quickly as the original parts we were born with. In fact, we should be able to even improve on the design, or as Steve Austin's boss said, we can build him "better than he was before. Better, stronger, faster."

Although bionics seemed like pure fantasy to most of us who were glued to our TV set each week back in the 1970's, the field of bionics has become reality faster than most of us would have imagined. One of the first successes in this area was the cochlear implant, introduced in 1991. This tiny bionic ear can allow some people with what used to be permanent hearing loss to hear again. Essentially, it recreates the ear's ability to send electrical impulses, representing sound, to the brain. The human ear has two main parts – the outer ear and the inner ear. It works by converting sound waves to electrical impulses that the brain can understand. The outer ear picks up sound waves and sends them to the inner ear, where a small, snail-shaped organ called the cochlea converts those waves into electrical impulses, which are sent directly to the brain.

Designed to mimic the function of the ear, a cochlear implant also consists of two main parts: an external part (like the outer ear) and an internal part (like the inner ear) which is surgically placed into the ear. The external device consists of a microphone, a sound processor, which converts the sound to an electrical signal, and a transmitter, which sends the signal to the implanted device. The internal device (like the inner ear) is consists of a receiver, which picks up the signals sent by the external transmitter and sends them to tiny electrodes implanted by a surgeon into the cochlea of the inner ear, next to the tiny nerve fibers that go back to the brain. The impulses are then sent to the brain along the same pathway that is used by a normal ear.

Current research is focusing on a much more daunting task: an artificial eye. Our eyes work by focusing an image on the retina, a small area in the back of the eye that has thousands of rods and cones, tiny receptors that convert the image into electronic impulses which are then sent to the brain.

Several designs for an artificial retina have been developed. Though not as successful as the artificial ear, some of these devices have restored rudimentary vision (light and shadows) to people who were blinded by disease many years earlier. One of the first clinically successful designs in this area came in 2000, from two brothers from Illinois, pediatric ophthalmologist Dr. Alan Chow and his brother, Vincent, an electrical engineer, who designed a chip that successfully restored limited black and white vision to six patients with Retinitis Pigmentosa, including a pair of twin brothers who, though close, had not actually seen each other for years.

There are two basics designs being studied. One utilizes a camera which sends signals to a small chip implanted in the back of the eye, while the other uses photoelectric cells imbedded directly onto the chip. In both cases, the chip converts the light signals to electrical impulses, which then travel back through the optic nerve to the brain. Another design currently in study is the neuromorphic chip, a complex microchip that is fabricated piece by piece to mimic the cellular architecture of the human retina. The progress has been remarkable, but none of these devices can restore perfect vision – yet.

Another area of research that has yielded promising prototypes is in the fabrication of prosthetic limbs, where medical research is currently making the transition from prosthetics (passive artificial devices that replace a lost limb) to bionics (limbs that are controlled by the human brain). Traditional prosthetic legs allow people to walk and prosthetic arms and hands allow people to manipulate objects, but both are limited in their effectiveness; none of today’s designs comes close to actually recreating the real thing, but new bionic limbs hold the promise of doing just that.

A prosthetic arm like the one Luke Skywalker received after his arm was cut off by Darth Vader in *The Empire Strikes Back*, seemed like pure fantasy when we first watched the drama unfold on the silver screen in 1980. But that kind of technology may not be too far off in our future. We already have many of the engineering skills to build such an arm, but making it part of the human body is quite another thing. Current research is working on various ways to accomplish this.

Myoelectric prostheses have been studied for years; they work by attaching electrodes to muscles in the residual limb. The wearer can then activate motors in the limb by flexing those muscles. A more recent advance, not widely available yet, is to use signals directly from nerves in the residual limb; the electrodes are connected to the nerves rather than the muscles. This creates a more direct path to the brain and more closely approaches the way we control our real arms and legs.

The newest technology in this area is focusing on highly refined brain-machine interfacing; in other words, a way to hook the artificial limb controls directly to our brain, so that we can move the mechanical arm with just a thought or even a subconscious gesture, just like we do with our natural arm. The only thing a prosthetic arm would lack at that point is sensation, something critical if the prosthesis is to allow us to truly interact with our environment in a natural way. This problem, in theory, can be solved by implanting sensory devices in the limb that will send signals back to the brain, enabling the wearer to actually feel what the limb is touching. Once we learn how to make these connections, a prosthetic limb should finally begin to approach the OEM (original equipment manufactured) part; we can all be like Luke Skywalker – sort of.

Nanomedicine

Nanomedicine, as described by Robert A. Freites, Jr., author of the book entitled *Nanomedicine,* is the "monitoring, repair, construction and control of human biological systems at the molecular level, using engineered nanodevices and nanostructures." The term *nano* is used because these devices are so small they have to be measured in nanometers – one nanometer is (10^{-9}) meters, thousands of times smaller than the width of a single human hair. We're talking really, really small here; in fact, the term *nano* is derived from the Greek work *nanos,* meaning dwarf.

Like many of my connections with science fiction, it was *Star Trek* that introduced me to the idea of nanomedicine. Although the premise was formulated by much greater minds than screenplay writers, it was the Borg, an evil empire that assimilated anyone they ran into, that sparked my interest in the field. The Borg brought their captives into "The Collective," by injecting them with nanites – microscopic robots that would enter the cells of the host and transform their prey into part man, part machine. In spite of the usual scenario of science fiction – that all new technology is abused for evil purposes – nanotechnology holds the promise of generating the greatest advances we have ever seen in medicine; perhaps, *even a cure for aging*.

Nanomedicine was first mentioned in 1959 by physicist Richard Feynman in a talk entitled "There's plenty of room at the bottom." His theory was that big tools could be used to make small tools, which in turn could make smaller tools, etc, down to a microscopic scale.

In 1981, an MIT grad student named K. Eric Drexler suggested that nanodevices might be constructed from biological parts, which could be designed to inspect and repair human cells. His theory was published in Smithsonian magazine in 1982, marking the introduction of nanomedicine to the public (and, no doubt, to the writers of *Star Trek: The Next Generation*), but a more technical version of his work was subsequently rejected by the *Journal of the American Medical Association* as nothing more than "science fiction."

As is usually the case, an increasing body of scientific evidence is gradually swaying the nay-sayers, and science fiction is once again morphing into basic science as nanomedicine gains acceptance as a promising new technology. Freites, one of its greatest proponents, designed a prototype nanomedicine robot called a respirocyte in the mid 1990's. He described this artificial red blood cell as "a spherical nanobot about the size of a bacterium," and two hundred times more efficient at carrying oxygen than a human RBC.

Medical research into the use of nanomolecules is advancing on several fronts, including the fabrication of new drugs and drug delivery systems far more effective than any known before. Scientists are designing new types of drugs that can seek out and destroy their targets, harmful invaders like bacteria or cancer cells. Another approach is to engineer new types of delivery systems for drugs we already have; nanomolecules carrying these drugs could be injected into the bloodstream and programmed to circulate throughout the body until they find their target -- the location of a tumor, for example. They would then release their drugs directly at the site the tumor. Compared to today's treatments, much smaller doses of those drugs would be necessary and exposure to healthy tissue elsewhere in the body would be limited. If successfully deployed in the human body, these techniques could increase the efficacy of drug treatment while vastly decreasing the harmful side effects.

The possibilities are endless. Though nanomedicine is still in its infancy, we are witnessing the birth of a revolutionary technology that will forever change medical care. But then again, you probably haven't paid attention to any thing I've written since I mentioned **a cure for aging**, have you? Just skimmed down to this spot, right? Well, here it is. Freitas speculates that if we can program nanobots to enter the human body, seek out and repair all malfunctioning cells, the little creatures could, in theory, reverse the damaging effects of cellular aging. Nanobots could one day be the true Fountain of Youth.

Is it really that simple?