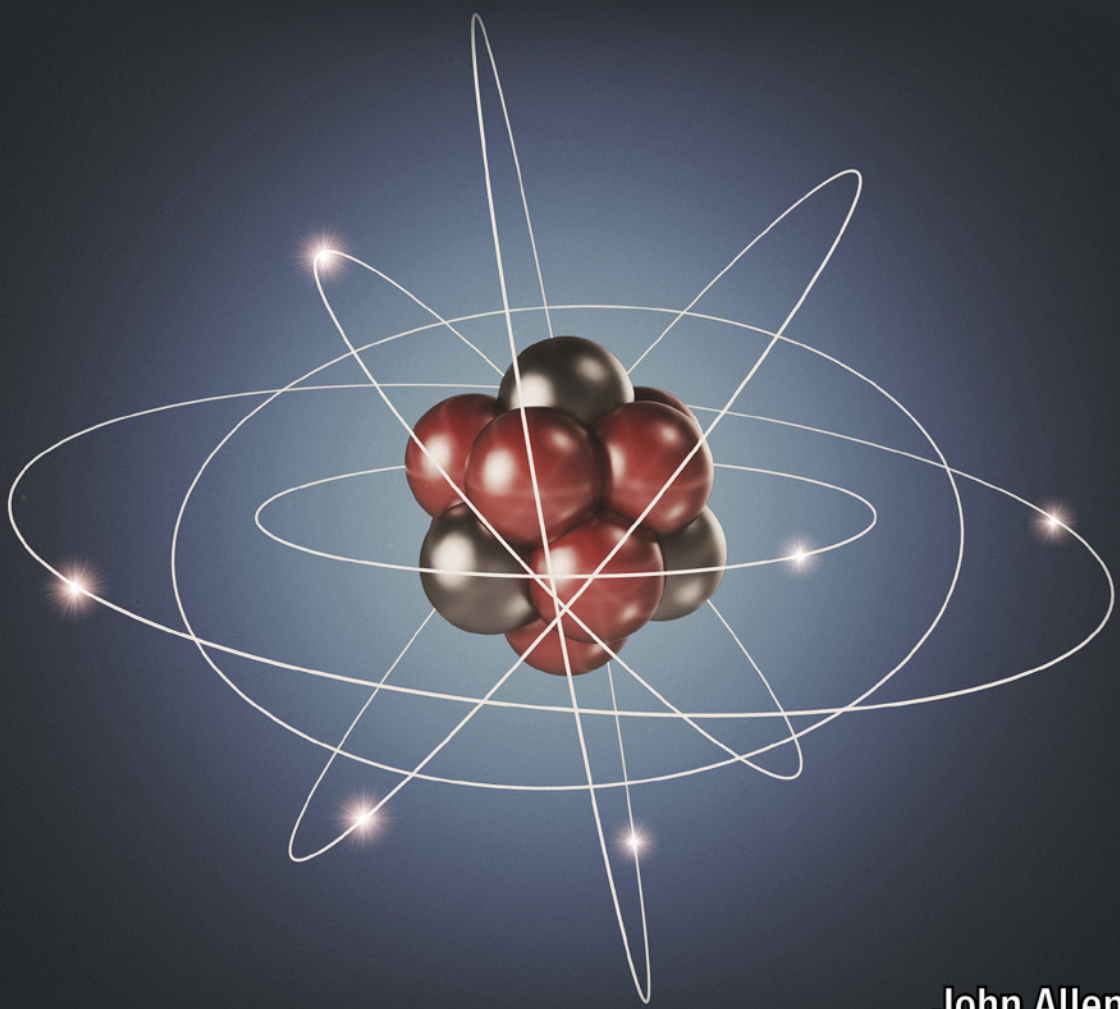
The Importance of SCIENTIFIC THEORY

The Importance of Atomic Theory



John Allen

CONTENTS

IMPORTANT DATES IN THE HISTORY OF ATOMIC THEORY

1680
Irish chemist Robert Boyle defines an element as something that cannot be broken down by chemical means, a perception that leads to the periodic table and ideas about atomic structure.

1900
German physicist Max Planck proposes the quantum theory, which says that electromagnetic energy can be emitted only in chunks called quanta (later renamed photons).

1898
English physicist Joseph John Thomson discovers the electron and proposes that negatively charged electrons are scattered throughout the positively charged sphere of an atom—the plum-pudding atomic model.

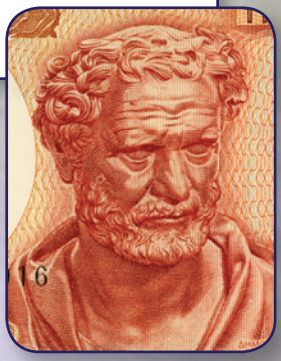
AD 1649
Pierre Gassendi, a French professor of mathematics, publishes a book that revives the idea that the universe is made up of atoms and the void.

BCE 600 / 1600 1700 1800 1900

1803
English chemist John Dalton develops an atomic theory that says all matter consists of small, indivisible particles called atoms; atoms cannot be created or destroyed; and atoms of different elements have different properties.

BCE ca. 400
The Greek philosopher Democritus develops the idea of his mentor Leucippus that the universe is made up of tiny, indivisible bits of matter called atoms.

1869
Russian chemist Dmitri Mendeleev creates the periodic table for a chemistry textbook, arranging elements according to atomic weights and properties.



1895
German physicist Wilhelm Roentgen discovers X-rays, which are charged electron particles flowing through a Crookes tube. The rays are able to pass through objects and produce images of the body's interior.

CHAPTER FOUR

Atomic Medicine: From X-Rays to DNA

At the end of August 2014 Brett and Naghemeh King whisked their five-year-old son Ashya out of a British hospital and took him to Malaga, Spain. The Kings had grown impatient with their son's doctors and were seeking a more advanced treatment for his brain tumor. They believed that proton beam therapy, a form of nuclear medicine, could save the boy's life. Unlike ordinary radiation treatments, which penetrate through the body and damage healthy tissue, proton beam therapy directs a more accurate flow of particles that stop once they hit their target. However, while proton therapy reduces harmful side effects, research shows that its success rate at treating cancer is about the same as that for radiation. Ashya's doctors had rejected the treatment as unlikely to succeed.

Days later the Kings were released from a Spanish jail after being arrested for moving their gravely ill son. Their arrest outraged those who believed the parents had every right to seek the best treatment. Jeremy Hunt, Great Britain's health secretary, acknowledged that the National Health Service does fund proton beam therapy, but the only proton beam machine in the country is a low-energy device used chiefly for eye surgeries. With regard to the technology, he added, "It's not always appropriate, it's not always safe."[22] Ashya's parents finally took their son to Prague in the Czech Republic for proton therapy treatment, and he is now expected to make a full recovery. The Kings' belief in the treatment is typical of how the public views nuclear medicine today. Atomic theory has led to technologies for diagnosing and treating illness that are used every day and are remarkably effective. Science continues to harness the properties of the atom to save lives.

Roentgen and X-rays

One of the most powerful diagnostic tools in medicine is the X-ray. The existence of X-rays was discovered almost by accident in 1895. Wilhelm Roentgen noted that attempts to photograph electric current passing through a Crookes tube left the photographic plates fogged and overexposed. Ruling out visible light as the cause, Roentgen sheathed his Crookes tube in black cardboard and ran an experiment. When he launched the current in the tube, a specially prepared screen coated with fluorescent paint began to glow, even though the screen was no closer than an adjacent desk. Roentgen found that the radiation from the tube passed through many objects—books, pieces of wood, even his own body. At his request, Roentgen's wife Anna placed her hand between the Crookes tube and a photographic plate. A ghostly image of the bones in her hand appeared on the plate. The effect must have been quite eerie, as Anna reportedly exclaimed, "I have seen my own death!"[23] Roentgen called the uncanny flow of charged electron particles X-rays, a temporary name that stuck.

Roentgen's discovery revolutionized medical science. Diagnoses of internal ailments could now be made without cutting into a patient's body. Because the rays passed through soft tissue but were absorbed by denser matter, X-ray images were able to reveal kidney stones and tumors. A year after Roentgen's work, an X-ray section opened at the Glasgow Royal Infirmary in Scotland—the world's first radiology department. X-rays showed a penny lodged in a child's throat and a needle in a seamstress's hand. During World War I, surgeons employed X-rays to identify cracked bones and embedded bullets. In 1927 a Portuguese physician named Egas Moniz developed a technique of x-raying arteries by injecting them with a contrasting agent. Angiograms, as they are called today, are crucial in monitoring heart disease and detecting blocked arteries. More recent developments in X-ray technology include computed tomography or CT scanning, in which cross-sectional images like slices of certain areas of the body are combined into a three-dimensional image, and fluoroscopy, which is the use of X-rays to provide a study of moving body structures, much like an X-ray movie.

Wilhelm Roentgen's discovery that radiation passes through objects, including the hand of his wife Anna, revolutionized medicine. X-rays, the name Roentgen gave to his discovery, allow doctors to diagnose internal ailments without cutting into a patient's body.

Early researchers working with X-rays soon discovered their dangerous effects. Patients exposed to the radiation for two hours at a time developed itching, irritation, and inflamed skin that resembled severe sunburn. Physicians finally realized that prolonged or repeated exposure can damage tissue and increase risks for cancer. This ability to destroy cells makes X-rays effective in treating malignant tumors. However, public awareness of the danger from X-rays has led to overreaction. Some patients are reluctant to submit to simple procedures such as dental X-rays. In reality, routine chest or dental X-rays pose no safety risk, nor do X-ray machines used in airport security. In any case radiologists and X-ray technicians are trained to employ the least amount of radiation necessary to get the results they seek. Certainly the benefits of this technology far outweigh the costs.

The Promise of Nanomedicine

Nanotechnology deals with manipulating extremely small bits of matter. It takes place on the level of atoms and molecules. One especially promising area for this technology is called nanomedicine. Researchers hope to enable doctors to treat disease and physical injury at the molecular scale. Some even see the potential for extending human life spans.

American physicist Richard Feynman raised the prospect of nanomedicine more than fifty years ago. "A friend of mine . . . suggests a very interesting possibility for relatively small machines," Feynman remarked. "He says that, although it is a very wild idea, it would be interesting in surgery if you could swallow the surgeon. You put the mechanical surgeon inside the blood vessel and it goes into the heart and looks around. It finds out which valve is the faulty [one] and takes a little knife and slices it out. . . . [O]ther small machines might be permanently incorporated in the body to assist some inadequately functioning organs."

Feynman's musings proved prophetic. Researchers today are developing tiny particles that are attracted to diseased cells in the body. The particles can repair or eliminate the bad cells without harming healthy cells. Another type of nanoparticle attacks a virus by delivering an enzyme that prevents the virus's molecules from reproducing. Scientists are also engineering microscopic robots, or nanobots, that can repair chromosomes in cells. With its endless applications, nanomedicine might well become the most important medical technology in the twenty-first century.

Quoted in Mallanagouda Patil et al., "Future Impact of Nanotechnology on Medicine and Dentistry," *Journal of Indian Society of Periodontology*, May–August 2008. www.ncbi.nim.nih.gov.

probe the secrets of DNA. Three years before Miescher's discovery a Central European monk and botanist named Gregor Mendel had described the basic process of genetics, but scientists did not understand the connection between genes and DNA. In 1944 American researcher Oswald Avery proved that genes, which pass on traits from parents to children, are encoded on the DNA molecule. Austrian chemist Erwin Chargaff was astounded by Avery's findings: "This discovery, almost abruptly, appeared to foreshadow a chemistry of heredity and, moreover, made probable the nucleic acid character of

the gene. . . . Avery gave us the first text of a new language, or rather he showed us where to look for it. I resolved to search for this text."[27]

Hopes and Fears About Genetic Research

Nine years after Avery's discovery, the English scientists James Watson and Francis Crick described the atomic structure of a DNA molecule as a three-dimensional double helix—like a circular staircase in two sections.

WORDS IN CONTEXT

genome

All the genetic material of an organism.

Their work led to a whole new area of science: molecular biology. Researchers began not only to study the processes of life on the subatomic level but to experiment with ways to affect these processes. The Human Genome Project enlisted scientists from around the world to collaborate on mapping and understanding human genes in their entirety. Results from this vast project were published in 2003.

A geneticist examines the results of DNA sequencing. Sequencing determines the make-up of genes, which are the sections of DNA that encode how every cell works. Genetic research has provided important new tools for tackling health problems at a molecular level.

IMPORTANT PEOPLE IN THE HISTORY OF ATOMIC THEORY

Aristotle (384–322 BCE) was a Greek philosopher considered the greatest thinker of the ancient world. He dismissed Democritus's atomism theory. Aristotle's views that all matter is infinitely divisible, that a void cannot exist, and that everything is made up of some combination of earth, air, fire, and water were accepted as dogma by the Catholic Church until the 1600s.

Amedeo Avogadro (1776–1856) was an Italian chemist who contributed to molecular theory with his observation that equal volumes of gases at identical conditions of temperature and pressure have the same numbers of molecules. Avogadro also proposed that simple gases are made up of compound molecules of two or more atoms.

Niels Bohr (1885–1962) was a Danish physicist who applied quantum theory to atomic structure to improve upon the planetary atomic model. Bohr realized that electrons' orbits are actually energy levels and when an electron drops from a higher to a lower energy level it emits energy in the form of a photon.

Robert Boyle (1627–1691) was an Irish chemist who performed important experiments on vacuums, the pressure of gases, and different chemical states. Boyle's insight that an element is something that cannot be broken down by chemical means led to the periodic table and the idea of atomic structure.

Robert Brown (1773–1858) was a Scottish botanist whose observations of the apparently random movements of pollen grains in water, called Brownian motion, led to Albert Einstein's groundbreaking paper on measuring molecules.

Marie Curie (1867–1934) was a Polish physicist who conducted important early research on radioactive materials and coined the term *radioactivity*.

FOR FURTHER RESEARCH

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INDEX

Note: Boldface page numbers indicate illustrations.