

## **From Sorcery to Scientific Revolution: A Brief History of Medicine and Science**

The history of medicine and science demonstrates the close relationship between these two fields. Scientific discoveries have allowed humans to understand the causal mechanisms of diseases and biological processes, and the application of this knowledge in medicine has led to improved diagnoses and individual treatment. Thus, medicine and science cannot be viewed in isolation. This essay will explore some of the key scientific theories and medical practices throughout history to illustrate the importance of empirical scientific knowledge in the maintenance of good health. In ancient medicine, empirical scientific evidence was not widely available and did not play a large role in medical practices in regions such as Ancient Egypt and Ancient China. Health and illness were closely related to the individual's relationship with the outer world. In Ancient Egypt specifically, treatment included sorcery, magical spells as well as surgery. During the classical period, the teachings of both Hippocrates (c. 460 BCE to c. 370 BCE) and Galen (c. 129 CE to c. 216 CE) reflected astrological influences, but also upheld a science-based approach to medicine. Hippocrates acknowledged that illness is due to natural, rather than supernatural causes. Importantly, Andreas Vesalius' work in the 16<sup>th</sup> century reflects a movement towards a scientific approach to medicine. Vesalius' focus on dissection and direct observation to gain anatomic knowledge saw human anatomy become an empirical science. Furthermore, scientific advancements in the 19<sup>th</sup> century by Robert Koch and Louis Pasteur established the connection between microorganisms and infectious disease. This fundamental scientific understanding led to medical advancements in the prevention and treatment of infectious diseases through vaccination. Additionally, the discovery of deoxyribonucleic acid (DNA) and its structure in the 19<sup>th</sup> and 20<sup>th</sup> centuries respectively, has led to genome sequencing and editing which continues to revolutionise the way medical professionals detect and treat non-infectious disease. Finally, this essay will discuss how

scientific advancements have allowed for the development of medical technology that provides highly accurate diagnosis and treatment for individuals, improving patient care. Ultimately, understanding the history of medicine and science enables us to appreciate how the application of scientific knowledge in the medical field has improved the quality of disease diagnosis and treatment.

Early medical diagnoses and treatments, such as those originating in Ancient Egypt and Ancient China, largely focused on the person's relationship with the external world, rather than empirical scientific evidence that indicated disease. In Ancient Egypt, there was no clear division between medicine and magic (Metwaly et al., 2021). Health and illness were due to an individual's relationship with the universe, which included other people, animals and spirits (Zucconi, 2007). According to Ancient Egyptian medical papyri, it was believed that the body had twenty-two vessels, which carried substances such as blood, mucus and tears around the body (Metwaly et al., 2021). The health of these vessels was judged by examining the patient's pulse, and disease was believed to occur if the vessels were blocked by foreign or poisonous substances (Metwaly et al., 2021). The papyri detail how herbal remedies, surgery and magical spells were used for treatment (Metwaly et al., 2021). Furthermore, in Traditional Chinese Medicine (TCM), disease is considered to be an imbalance in the body's system, causing illness to arise from an internal or external source (Köhle, 2023). Notably, bodies are affected by seasons and surroundings. Foundational to TCM is the concept of qi, which is commonly translated as 'energy', and the five element theory, where each natural element is attributed to an organ (Köhle, 2023). According to TCM theories, if the body's inner qi is in harmony with outer qi (in the external world) this results in health. However, an imbalance between inner and outer qi can result in illness. This is determined through diagnostic methods including grasping the mai (pulse examination) and tongue diagnosis (Köhle, 2023). TCM treatments include herbal medicine, acupuncture, moxibustion, massage and cupping (Köhle, 2023). Thus, ancient

medicine was largely based on subjective diagnosis and treatment for which there was little empirical scientific evidence.

During the classical periods, particularly in Classical Greece and Rome, scientific understanding of health and disease was influenced by the teachings of physicians Hippocrates and Galen. Preserved in the Hippocratic Corpus, Hippocrates' teachings describe good health as a balance between bodily fluids and external factors. Hippocrates acknowledges how illness is due to natural, rather than supernatural, causes (Leonard, 2019). Hippocrates' teachings reflected a science-based approach to medicine, separating medical practice from religious worship (Leonard, 2019). Hippocrates, followed by Galen, both believed that the body consisted of four "humors", or bodily fluids: phlegm, blood, yellow bile and black bile (Hajar, 2021). These were to remain in balance to ensure good health. Illness occurred when one humor was in excess. To treat this, the fluid, such as blood, would be removed by methods such as bleeding (Hajar, 2021). Notably, astrology influenced the medical theories of both Hippocrates and Galen. The Hippocratic Corpus describes how heavenly bodies, specifically the moon, affect human health, where the moon's phases corresponded to "critical days" of illness (Greenbaum, 2014). Hippocrates also details the body's solar connection, linking the four humors to the seasons. In Galen's commentaries on Hippocrates, he linked "critical days" very precisely with the phases of the moon (Pennuto, 2008, as cited in Greenbaum, 2014). Subsequently, medieval medicine was largely influenced by Hippocrates and Galen (Hajar, 2021). Reflecting the influence of astrology, the human body was considered a "*parvus mundus*", a microcosm that was part of the greater cosmic (Cassirer, 1943). The heart was regarded as the sun, while the other organs were associated with various planets (Cassirer, 1943). Hippocrates' substantial impact on medicine is evident in modified versions of the Hippocratic Oath, a code of essential principles encouraging new physicians to swear to uphold

professional ethical standards, which is still administered by medical schools today (Hajar, 2017).

The advancements in science during the 16<sup>th</sup> and 17<sup>th</sup> centuries are traditionally referred to as the “Scientific Revolution” (Rabin, 2017). This period saw immense advances in the experimental method, where physicians such as Andreas Vesalius promoted a highly scientific approach to medicine. Vesalius defied scholastic tradition as his work was characterised by observations and experiments rather than abstract theories (Cassirer, 1943). Through Vesalius’ focus on dissection to gain anatomic knowledge, human anatomy became an empirical science (Benini & Bonar, 1996). At this time, the study of the human body was closely linked with mythic speculations; gaining knowledge about human anatomy was achieved by studying texts such as Galen’s *Anatomicae Administrationes* (Benini & Bonar, 1996). Vesalius played a key role in challenging the traditional hierarchy of sciences which was based on the concept that the rank and dignity of a certain science depended upon its subject matter (Benini & Bonar, 1996). God is the highest in this traditional hierarchy and theology is superior to all sciences (Cassirer, 1943). Medicine, being a science of the body, which temporal, rather than eternal, had a low rank in this scale. Specifically, for anatomy, the subject matter is the dead body, rather than a living body. Therefore, as the dead body is considered extremely low in this hierarchy (Cassirer, 1943), the use of dissection in teaching had low value (Benini & Bonar, 1996). Leonardo da Vinci first challenged this principle by emphasising that the value of science instead depends upon the degree of certainty achievable, rather than its subject matter. Due to Vesalius’ dissection work, anatomy was elevated to a degree of certainty that it had never previously possessed, and it became a pure, empirical science (Benini & Bonar, 1996). In his work *De Humani Corporis Fabrica* (Of the Structure of the Human Body), Vesalius published extensive anatomical illustrations based on his observations. Furthermore, despite the bones being the last reached during a dissection, Vesalius believed that osteology should

be learnt first when studying anatomy. This is reflected globally in the courses of modern medical schools (Benini & Bonar, 1996). The majority of modern nomenclature can also be attributed to Vesalius. He closely studied the spinal cords and nerves, naming the spinal foramina *foramina nervis emittendis parata* (Benini & Bonar, 1996). Ultimately, Vesalius' contribution to the understanding of human anatomy largely increased the empirical evidence available in this area, which is still applied to medical practice today.

Scientific advancements in microbiology by Robert Koch and Louis Pasteur in the 19<sup>th</sup> century established the link between microorganisms and infectious diseases, creating a foundational understanding that would lead to medical advances in the prevention and treatment of infectious diseases. Koch developed a set of criterion, called Koch's postulates, that must be met to prove that a specific pathogen causes a specific disease (Van Zyl, 2021). This fundamental tool is highly applicable to modern medical research. Importantly, Koch identified the bacterium that caused anthrax, *Bacillus anthracis*, and the bacterium that caused tuberculosis, *mycobacterium tuberculosis*. Koch's method led to a greater understanding of prevalent diseases. In the span of 30 years, beginning in 1976, over 20 bacterial pathogens were identified for diseases such as tetanus, typhus and the plague (Lakhtakia, 2014). By establishing that a certain pathogen could cause a certain disease, Koch developed the foundation for identifying infectious microorganisms (National Research Council (US) Committee to Update Science, Medicine, and Animals, 2017). Furthermore, the theory of spontaneous generation, articulated by early Greek scholars such as Aristotle, proposed that life could arise from non-living matter (LibreTexts, 2016). Francesco Redi's 1668 experiment was among the first to refute the belief that maggots spontaneously generated from meat left in the open air (LibreTexts, 2016). As hypothesised, the meat in the open containers saw the formation of maggots whilst maggots did not appear on the meat in the tightly sealed or gauze-covered containers. Redi concluded that maggots were not the product of spontaneous generation, but

rather, they were the offspring of flies. Despite these findings, some argued that spontaneous generation may still be relevant to smaller microbes, and the theory continued to engender debate until Pasteur indisputably disproved the theory in 1858 (LibreTexts, 2016). Pasteur's experiment consisted of numerous flasks containing sterilised broth. The flasks were either long "swan-neck" flasks, which prevented the entry of any airborne microorganisms, or broken neck flasks, which allowed air to enter the flask. As predicted, the sterilised broth remained sterile in the swan-necked flasks, however, microbial growth appeared in the broken-necked flasks (LibreTexts, 2016). Pasteur concluded that microbial growth could not arise from nonliving things and that microorganisms were instead carried in the air (Mendelsohn, 2002). Pasteur disproved the spontaneous generation theory, leading to the germ theory of disease, which states that diseases are caused by microorganisms, rather than spontaneous generation.

Importantly, subsequent vaccine development by both Pasteur and later scientists was influenced by germ theory. Pasteur produced an attenuated (weakened) culture of the microorganism that caused cholera in chickens and it conferred immunity when inoculated (Mendelsohn, 2002). Thus, Pasteur developed his principle of non-occurrence, which means that a first infection provides protection against subsequent infections (Mendelsohn, 2002). Furthermore, Pasteur advanced Koch's work with anthrax. Through the attenuation of *anthrax bacillus* Pasteur developed the first anthrax vaccine. Both Koch and Pasteur demonstrated how vaccines could be used to prevent bacterial infections. These principles of vaccination have influenced the development of numerous vaccines, leading to a wide availability of vaccines in the 21<sup>st</sup> century for both viral and bacterial diseases. As a consequence of effective vaccinations, the last naturally occurring case of smallpox was in 1977, and since the commencement of the Global Polio Eradication Initiative, polio cases have decreased by over 99 percent (CDC, 2023). Therefore, understanding the scientific principles and mechanisms behind infectious disease has resulted in the development of preventative measures, such as

vaccines and has also led to stricter infection control measures and hygiene regulations in healthcare settings (Lakhtakia, 2014).

Humanity's enhanced scientific understanding of genetic material has led to the creation of new techniques to diagnose and treat non-infectious (genetic) diseases. In 1869, Swiss physician and biologist Friedrich Miescher discovered the chemical substance DNA (Mirsky, 1968). In 1944, Oswald Avery discovered that DNA was a human's genetic material, and Erwin Chargaff later demonstrated that the proportion of bases in DNA followed strict laws (Portin, 2014). These findings, along with the X-ray diffraction work of Maurice Wilkins and Rosalind Franklin, contributed to the discovery of the double helical structure of DNA by James Watson and Francis Crick in 1953 (Portin, 2014). The Watson-Crick model explains how genetic material replicates, the content of genetic material and how genetic material can change and mutate (Portin, 2014). The Watson-Crick model specifically explains how DNA transmits genetic information: through a complementary base pairing system (Portin, 2014). Subsequently, Matthew Meselson and Franklin W. Stahl were able to perform experiments to show that the semi-conservative model was the correct model to explain the mechanism of DNA replication (Portin, 2014). In the 1960s, multiple studies confirmed the role of messenger RNA in protein synthesis (Portin, 2014). Bacterial restriction enzymes were soon discovered, and scientists were able to develop techniques to manipulate genes through isolation, cloning and sequencing (Portin, 2014).

This scientific understanding of the human genome, propelled by the discovery of DNA's structure, enabled the Human Genome Project to commence in 1990. The Human Genome Project aimed to determine the chemical makeup, or DNA sequence, of the whole human genome (Collins & Fink, 1995). It was completed in April 2003. Understanding the structure, function and sequence of humanity's genetic material has resulted in highly important medical applications. Genetic mapping has allowed researchers to track the

inheritance of a disorder and map anomalous markers (Collins, 1999). Scientists can use this information to predict the development of a genetic disease later in an individual's life and intervene early to prevent illness. Reducing disease through treatment has been successful for hereditary disorders such as hemochromatosis and familial hypercholesterolemia (Collins, 1999). Furthermore, genome technology allows for positional cloning which is a gene isolation technique enabling researchers to identify genes responsible for certain diseases. The isolation of genes responsible for breast cancer, namely *BRCA1* and *BRCA2*, has led to the development of personalised treatment for individuals with the disease (Rossing et al., 2019). Furthermore, CRISPR, which stands for Clustered Regularly Interspaced Short Palindromic Repeats, is a gene editing technology which can permanently modify genes to treat genetic causes of diseases such as Cystic Fibrosis, Muscular Dystrophy and Huntington's Disease (Fernández, 2019). Notably, genomics research has significantly impacted clinical medicine. Genomic technologies such as gene sequencing can be applied to develop and increase the efficacy of drugs in areas such as neuropsychiatry, cardiovascular medicine and oncology (Emilien, 2000), where treatments can be tailored to individuals' genetic makeup.

Historical technological and scientific advancements have transformed medical research, diagnosis and treatment, allowing for more personalised medical solutions. Over the last 100 years, digital data and technological improvements have revolutionised medical imaging. Techniques such as the electroencephalogram (EEG), magnetic resonance imaging (MRI), positron emission tomography (PET), computed tomography (CT) and ultrasound (US) have enabled more efficient and accurate diagnoses and subsequently, treatment for patients (Rego & Tan, 2006). Moreover, three-dimensional printing technology has been used to create implants and bespoke prosthetics, reflecting a highly personalised approach to treatment (Burke, 2022). However, with significant technological advances, ethical issues inevitably arise, for example: privacy and confidentiality, informed consent, negligence, the use of human

subjects in clinical trials and affordability. Specifically, Silverman (2004) uses the following example to demonstrate how privacy issues may arise surrounding the use and availability of information gained from genetic technologies. Suppose genetic technologies can determine that a three-year-old is likely to develop a life-threatening heart disease later in life. Who has a right to this knowledge? Do parties such as prospective employers or insurers have a right to this knowledge? Evidently, advances in science that lead to the development of beneficial medical technologies are accompanied with important ethical issues which cannot be overlooked.

Thus, the interconnected history of medicine and science demonstrates the increasing role and importance of empirical research in understanding the human body. Medicine during ancient and classical periods was not guided by rigorous scientific experiments and knowledge, but rather characterised by subjective diagnoses and influenced by astrological patterns. From the 16<sup>th</sup> to the 19<sup>th</sup> century, Vesalius' contribution to understanding human anatomy as well as Koch and Pasteur's work in microbiology indicates a shift towards gaining empirical knowledge through observation and precise experimentation. This has had widespread applications in the medical field, notably, contributing to vaccine development. In the 21<sup>st</sup> century, contemporary medical challenges, such as the prevention and treatment of genetic disease, drive scientific inquiry. Developing medical technology that can improve individuals' quality of life whilst considering ethical issues calls for the global collaboration of scientists and medical professionals alike.

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