# Why is Chemistry important?

Chemistry is defined as the study of matter and its reactions under different conditions; from the air that we breathe in, to the clothes that we wear chemistry is fundamental to the basis of our everyday lives. It explains the world around us, allows the development of new materials for technology and infrastructure, proposes solutions to the climate change crisis and one of the most important fields which chemistry contributes to is health. This essay will discuss three key areas; drug discovery & development, drug delivery and finally medical testing alongside diagnosis where the use of chemistry is crucial to ongoing development both past, present and future. However, we are all very aware that chemistry is at the heart of all future discoveries. This is the science that will revolutionise medicine by allowing the production and faster testing of more effective medicines, the future application of nanoparticles to deliver drugs with a higher bioavailability to areas of the body which were untreatable before and to further improve the testing and diagnosis to predict diseases much faster by detecting early warning signs.

Drug discovery is the way that new medicines and drugs are developed which have therapeutic effects on targets within the body such as an enzyme, muscles, protein or receptor; the modern, very much chemically involved process, can be broken down into therapeutic content selection, target validation and lead selection. Chemistry is essential for these processes because it allows the design, synthesis and modification of the process of drug development. Drugs can either be synthesised by using natural products, for example aspirin is composed of salicylic acid from the bark of willow trees to form acetylsalicylic acid and digoxin which originates from a foxglove plant, or they can be synthesised from small molecular units by created by utilising chemical synthesis where a series of smaller reactions allow a compound to be made from smaller starting materials. This process can however take a long time to complete because of the large number of steps in the process so using natural products is preferred. Molecules which have the potential to produce positive therapeutic effects, and therefore may potentially be successful new drugs, can be identified with the use of high input screening where chemists can test whether molecules have binded to the specific target cells producing a hit (positive) result which are further studied to test their toxicity and pharmacokinetics to assess if the drug candidate can continue to the next stage of preclinical testing. Chemistry is vital for this process as the understanding of the physical structure, purification of possible lead compounds and chemical synthetic techniques allow new molecules to be produced with improved properties by using SAR analysis (structure activity relationship)/ By altering the chemical structure of the drug, the solubility, stability and bioavailability can be altered to better fit the purpose of the drug. Furthermore, it is necessary to carry out medical optimisation to improve the outcome, reduce waste of medicines and to increase safety of the drug; this process, despite not being commonly known about, is crucial as the WHO (World Heath Organisation) estimated that 30%-50% of drugs are not used correctly (2003 WHO report) and in the UK alone 25% of the population have a long term condition; the impact of this is that patients may not receive the benefit of the medication and so if in drug optimisation the structure can be modified to improve ease of use and to minimise any deficiencies found in their structure then this can potentially increase the patient ease of use and therefore decrease the percentage of those misusing the medication. Historically without the understanding of chemistry, drugs were developed using trial and error experimentation and observation of human and animal reactions to these products which was hugely unsuccessful when applying the potential drugs to human uses; the National Institute of Health discovered that 95% of all drugs which are proved as safe and effective in animal trials then go onto fail in human trials because they do not have the desired effect or cause harm to humans. This demonstrates that the traditional method of developing drugs without the chemical knowledge is ineffective and results in a waste of resources. The mean global average cost of developing a drug is US$1.3bln (London School of hygiene and Tropical medicine); without chemistry the success of drug development is compromised because chemistry plays a key role in every stage from synthesis to optimisation in which the pharmaceutical applications of chemistry result in new molecules that can cure diseases and generally improve human health.

Drug delivery is the process of transporting drugs to their target cells while reducing their degradation or elimination in the process. One of the major issues in the drug delivery process is getting drugs through barriers in the body that prevent drugs from reaching their target site; these include the plasma cell membrane, the skin and the blood-brain barrier. Chemistry allows nanoparticles to be used to carry drugs to their target cells which include liposomes, antibodies and nanoparticles; these systems allow controlled release, targeted delivery, improved biocompatibility, reduce the body's immune response and increase circulation time. 80% of drug targets are inside cells which makes it difficult for larger molecules to access them; therefore, nanoparticles are essential because they are less than 100nm by definition and so they are small enough to get through these barriers. As a consequence, specific areas of cells that could not otherwise be targeted to treat diseases can be accessed. Currently the nanoparticles used are made from lipid nanoparticles (LNP) and a team led by Fredrik Höök and Elin Esbjörner at Chalmers University of Technology are making considerable progress in getting mRNA across the plasma membrane by using LNPs because of the hydrophilic and hydrophobic sections of the phospholipid bilayer which don't allow charged particles, like mRNA, to cross. By using LNP they have been able to get their mRNA to cross the plasma membrane and reach the ribosomes so that proteins with this mRNA can be synthesised; their research has found that the use of LNP has allowed the bioavailability of their drug to increase from 1%-2% without LNPs to 10% with LNPs. This is a significant increase and will mean that the dose of the medicine can be reduced so the side effects of taking the drug will be reduced which will both improve the quality of life for the patient and reduce cost. In addition, chemistry can allow drug delivery systems to control the release and distribution of drugs throughout the body by using substances that respond to physical environment changes like pH, temperature or enzymes. Despite the abundant advantages of using particles like LNPs the number of studies is still limited and only a few drugs released onto the market, for example doxil which is an LNP which causes the formation of the antitumour agent doxpruicin to treat ovarian cancer, and therefore the long term effects of using nanoparticles in medicine are still unknown. There is no doubt that the use of nanoparticles is an innovative solution to the current limitation of crossing barriers within the body and could not happen without the existence of chemistry and will undeniably therefore play a significant role in medicine in the future.

Medical testing allows biological markers, which indicate illnesses and disease, to be measured and monitored over time to diagnose and treat patients. The field of clinical chemistry focuses on quantitative tests using analytical techniques and specialised equipment. Most commonly the bodily fluids tested and used to diagnose are blood and urine and they are mostly tested for the presence of enzymes, hormones, proteins, glucose and other metabolic substances. For example, blood glucose tests can be used to test whether a person has diabetes by checking the levels of sugar in the blood and urine tests can determine the ratio of lipoproteins in plasma compared to the amount excreted in urine. Extensive results demonstrate that advancements in chemistry have led to medical testing advances for example, the development of new materials such as microfluidics, nanotechnology and biosensors. These have allowed the creation of portable testing machines such as biosensors which carry out the blood glucose tests mentioned above and can produce a result in seconds. The glucose biosensor is based on an oxygen electrode where an immobile layer of glucose oxidase is put onto of the oxygen electrode and a semipermeable dialysis machine is put on top of that; this means that when exposed to glucose the reaction catalysed by enzymes occurs which causes a localised consumption of oxygen and so the current being generated at the oxygen electrode drops. This is an example of a direct application of chemistry technology, an oxygen electrode, in medical testing which can lead to the diagnosis and maintained assessment of diabetes in a patient. Chemistry can also help to explain the outcome of tests for biological molecules such as the frequently used test for starch; in the test for starch potassium iodide is added to a sample and if starch is present then there will be a blue-black result which is due to the formation of a polyiodide complex between iodine and starch. Starch is a polysaccharide so is made of long chains of glucose molecules and so form helical structures which trap iodine molecules inside the helix because the iodine is attracted to the inside of the coil; when iodine is trapped inside the coil light is prevented from passing through and so the solution appears a blue-black colour. Therefore, chemistry is crucial to medical testing both in terms of carrying out tests and explaining test results. In the future there is expected to be further growth in terms of the technology available for testing especially in the field of molecular genetics; currently a genetic test can identify one or more mutations of DNA in a gene which cause disease with a distinct pattern of inheritance, dominant or recessive. In the future the applications of this are that for every disease genetic links will have been found which even if not directly caused by mutations (resulting in a completed database for all diseases) will dramatically improve the ability to use genetics to accurately predict the likelihood of an individual developing a disease. This will only be made possible by the further chemical advances in the development of new diagnostic tools and techniques which are even more sensitive, specific and portable. It is undeniable that the importance of chemistry to the medical and biological advancements cannot be underestimated as it will provide the future for sequencing, testing and research developments.

In conclusion, chemistry is a crucial subject across all areas of life, especially in terms of health and medicine; as evidenced by the drug development, drug delivery and medical testing leading to diagnosis. It is clear that these three categories demonstrate the importance of chemistry at the heart of all future scientific progress, especially medical technologies. Without the application of chemical analytical techniques and knowledge these significant advances, and future advances, simply cannot be possible, therefore chemistry is not only important but also imperative in the future of scientific discovery and achievement.

Bibliography:


'9 Famous Examples of Drugs That Came From Plants'. The Sunlight Experiment, 22 June 2018, https://thesunlightexperiment.com/blog/2018/6/7/9-famous-examples-of-drugs-that-came-from-plants.

'Answers to Common Arguments for Animal Testing'. PETA, 23 June 2010, https://www.peta.org/issues/animals-used-for-experimentation/animal-testing-bad-science/.

Average Cost of Developing a New Drug Could Be up to $1.5 Billion Less than Pharmaceutical Industry Claims | LSHTM. https://www.lshtm.ac.uk/newsevents/news/2020/average-cost-developing-new-drug-could-be-15-billion-less-pharmaceutical. Accessed 24 Apr. 2023.

Chopra, Bhawna, and Ashwani Kumar Dhingra. 'Natural Products: A Lead for Drug Discovery and Development'. Phytotherapy Research: PTR, vol. 35, no. 9, Sept. 2021, pp. 4660–702. PubMed, https://doi.org/10.1002/ptr.7099.

Connelly, Dawn. 'A History of Aspirin'. The Pharmaceutical Journal, 26 Sept. 2014, https://pharmaceutical-journal.com/article/infographics/a-history-of-aspirin.

Developing the next Generation of Drug Delivery Technologies. 4 Apr. 2023, https://www.astrazeneca.com/what-science-can-do/topics/next-generation-therapeutics/developing-the-next-generation-of-drug-delivery-technologies.html.

Editorial, PharmaCentral. 'Drug Discovery and Development: A Step by Step Guide'. PharmaCentral | Materials and Knowledge Platform, 22 Oct. 2021, https://pharmacentral.com/learning-hub/technical-guides/drug-discovery-and-development-a-step-by-step-guide/.

Leonard, D. G. B. 'The Future of Molecular Genetic Testing.' Clinical Chemistry, vol. 45, no. 5, 1999, pp. 1–5, https://doi.org/https://www.nature.com/articles/nrd1523.

Lombardino, J. G., and J. A. Lowe. 'The Role of the Medicinal Chemist in Drug Discovery - Then and Now, '. Oxford Academic, vol. 3, no. 1, 2004, pp. 853–62.

NHS England » Medicines Optimisation. https://www.england.nhs.uk/medicines-2/medicines-optimisation/. Accessed 24 Apr. 2023.

Types. https://stanfordhealthcare.org/medical-tests/l/lab-tests/types.html. Accessed 24 Apr. 2023.

Yadav, Madhu, et al. 'A Significant Role of Chemistry in Drug Development: A Systematic Journey from Traditional to Modern Approaches with Anti-HIV/AIDS Drugs as Examples'. Current Pharmaceutical Design, vol. 28, no. 3, 2022, pp. 232–47. PubMed, https://doi.org/10.2174/1381612827666211102101617.

Yetisgin, Abuzer Alp, et al. 'Therapeutic Nanoparticles and Their Targeted Delivery Applications'. Molecules, vol. 25, no. 9, May 2020, p. 2193. PubMed Central, https://doi.org/10.3390/molecules25092193.