Serendipity and scientific discoveries

Pablo Picasso used to say: 'Inspiration exists, but it has to find us working.' What did he mean? Do you think we can find similar situations in science? Have you ever thought about how scientists come up with brilliant ideas to solve problems? Germán Tenorio explores the role of serendipity in science

The nature of science (NOS) section in the IB guide of the science courses (biology, chemistry and physics) helps us to realise and understand that science (and scientific work) is not just carried out by a single scientist following several steps of the scientific method. Actually, science depends on interactions with the shared knowledge within the scientific community, repeating the different parts of the scientific method by different people at different times in order to obtain new information. In addition, the scientific process is not something static carried out in a lab, but it is a dynamic and, most of time, unpredictable process. Finally, creativity is an important factor in science, because in discovering new things or explanations to a problem, new approaches to the same problem must be given.

Science is mostly based on careful observations behind a tireless process of research, such as the use of Rosalind Franklin's X-ray diffraction, which provided definitive evidence that DNA is a double helix, or Michael Faraday's observation of electromagnetic induction. However, some of the most important discoveries, such as the discovery of penicillin or radioactivity, are clear examples of how lucky events have a deep impact on scientific discoveries.

You may think that someone could make a scientific discovery by a stroke of luck, but in fact, this is far from being true. Although anyone could a find a coin on the ground by chance, not everybody can realise that an incorrect result from an experiment can be used as an application to solve another problem. Scientific discoveries where chance is involved are known as **serendipitous events**.

Serendipity and TOK

Although the word 'serendipity' is often used as a synonym for 'chance', serendipity is not just chance. While we recognise chance as something opposite to rationality or critical thinking, serendipity presupposes a fluency with relevant knowledge that has already been established in a community. In this sense, serendipity is defined as the rational exploitation of chance, especially in the discovery of something useful or beneficial. One important aspect that has to be taken into account in order for an event to qualify as serendipitous is that the thing discovered is something that the discoverer had not been looking for.

So serendipity is associated with discoveries that are not just down to chance, but arise from it, together with an intellectual effort that derives the discovery from the chance event. The TOK course identifies eight specific ways of knowing. Intuition is one of them, which is often regarded as knowing without the use of rational processes. To what

extent might some of these scientific discoveries be the result of intuition rather than luck?

Discovery of penicillin

There are many examples of scientific discoveries associated with serendipity, especially those where cures were discovered for infectious diseases. One of the most well known serendipitous discoveries was the discovery of penicillin, the first antibiotic, by Alexander Fleming, professor of bacteriology at St Mary's Hospital, London, in 1928. After returning from his summer holiday, he began to sort through Petri dishes containing colonies of the *Staphylococcus aureus* bacteria that he had left on the bench. He noticed that one dish was dotted with colonies except for an area where a contaminating *Penicillium* mould had grown. The zone around the mould was clear, as if the mould had secreted something that inhibited bacterial growth.

Fleming found that the mould was effective not only against *Staphylococcus* but also a wide range of pathogenic bacteria, such as those causing pneumonia, meningitis, gonorrhoea, scarlet fever and diphtheria. Studies estimate that up to 200 million lives have been saved by Fleming's discovery, approximately twice the number of casualties in the Second World War.

Fleming discovered penicillin thanks to a stroke of luck, but could anyone have taken advantage of this chance observation? Probably not, because in serendipity, apart from being smart, a solid academic training in a discipline is essential. As Louis Pasteur said: 'Chance favours the prepared mind.' In TOK we talk about the shared knowledge of a community. In this case Fleming's previous expertise in science and his fluency with the concepts and methodologies meant that he immediately recognised the importance of this new observation. In fact, during his Nobel lecture in 1945, Fleming said:

> 'It arose simply from a fortunate occurrence which happened when I was working on a purely academic bacteriological problem which had nothing to do with antagonism, or moulds, or antiseptics, or antibiotics... . Penicillin started as a chance observation. My only merit is that I did not neglect the observation and that I pursued the subject as a bacteriologist.'

Theory of knowledge

1 Do you think that the role of serendipity makes the scientific method more or less reliable?

2 What role does an individual's understanding of the shared knowledge of a community play in serendipity?

3 Richet's discoveries depended on experiments on live animals, something many think should not be part of the scientific method. If an experiment violates the ethical treatment of test subjects, does that make the knowledge gained more or less valuable?

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References and resources

The discovery and development of penicillin: www.tinyurl.com/ln2hyue

Accidental discoveries: www.tinyurl.com/8yo32yb

Becquerel's discovery of radioactivity: www.tinyurl.com/y72f6j68

Viagra and other drugs discovered by accident: www.tinyurl.com/ya45dozl

www.understandingscience.org

Meperidine for morphine

Another serendipitous discovery took place in the 1930s when the Austrian physiologist Otto Schaumann was studying an antispasmodic compound in rats while he was working at IG Farben, a German chemical company. He noticed that the tails of treated rats assumed an S-shaped curvature that had been reported previously for rats given morphine or other opioid analgesic drugs. Although the compound was not structurally similar to morphine, it proved to be a narcotic analgesic. Later, it was shown that this compound, now known as meperidine, has some structural features in common with morphine and they have the same active area. Meperidine was found to be less potent than morphine, causing fewer side effects and acting faster. Nowadays this drug is widely prescribed to treat moderate-to-severe pain under such trade names as Demerol in the USA.

The sudden appearance of S-shaped tails in treated rats is something that anyone could observe, but not everybody would have the shared knowledge or insight to associate it with the pharmacology of morphine. In TOK we differentiate between shared and personal knowledge. To what extent does personal knowledge not exist in scientific research? Under what circumstances should personal knowledge gained by scientific research not be shared?

Allergens and anaphylaxis

Fifteen years before Fleming's happy accident, French physiologist C. R. Richet starred in a lesser-known serendipitous event. He was studying how toxins affect the body by injecting trace amounts of poison from the tentacles of sea anemones into dogs. The allergic symptoms — including vomiting, shock and loss of consciousness — took some time to appear. Some of the dogs died from allergic shock, but others survived their reactions and recovered completely.

After some weeks, as the recovered dogs seemed completely normal, Richet made use of them together with new dogs for more trials. After they were given another dose of anemone poison, he noticed that symptoms took some time to turn up in the new dogs, as usual, but interestingly the recovered dogs suffered serious symptoms just minutes after the poison was administered.

Richet realised that he could not ignore the unexpected results of his experiment, so he kept researching, treating more recovered dogs with different doses of the poison. He proved that when an individual is exposed to an allergen a second time, the individual is even more sensitive to its effects than the first time, as the ability of the immune system to respond has been affected. His conclusions established the basis of allergic reactions and in 1913 Richet received the Nobel prize in recognition of his work on anaphylaxis.

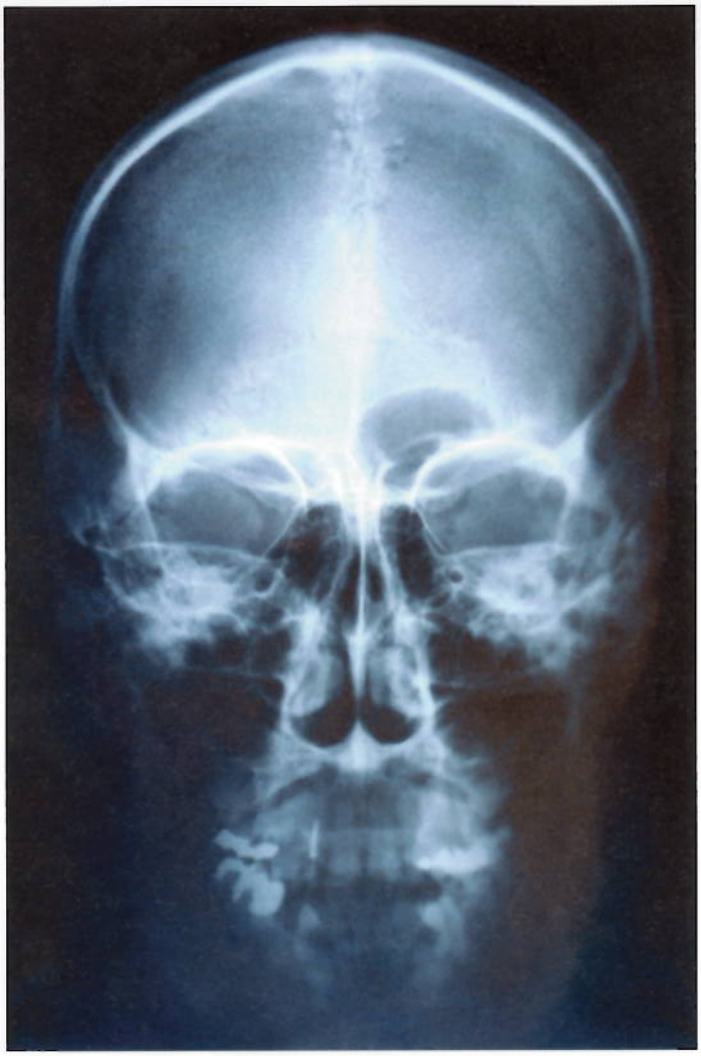
Today we know that anaphylaxis is an exaggerated immune reaction involving immunoglobulin E antibodies as well as mast cells and basophils, which can affect several organs and may cause death. There is no specific data available about how many deaths have been avoided due to this discovery, but millions of allergic people have been positively impacted and even saved by the discovery of anaphylaxis.

Many serendipitous events are related to the discovery of new drugs. Further examples can be found in scientific literature, such as discovery that Viagra was an effective treatment of impotence in men (the drug was being investigated to fight angina and hypertension), or the discovery of levamisole, a successful treatment to kill parasitic worms in livestock that scientists realised by chance was synthesised naturally by the chickens.

Discovery of radioactivity

One of the most well known and important accidental discoveries in medical science took place in physics, when another French scientist, Henri Becquerel, discovered spontaneous radioactivity in 1896. Becquerel was studying uranium and phosphorescence, and subsequently discovered X-rays. These later turned out to be useful for medical imaging, since X-rays can penetrate human body flesh.

At the time, Becquerel thought that phosphorescent uranium salts he had been studying might absorb sunlight and reemit it as X-rays. To test this, Becquerel placed crystals of uranium salt on top of photographic plates that had been wrapped in black paper so that sunlight could not reach them. When he developed the plates, he saw that the plates



were clear except for an outline of the rock crystals. Becquerel took this as evidence that his idea was confirmed: he reasoned that the rays creating the image originated in the Sun, but had been transformed into X-rays, not realizing that the uranium crystals themselves were the source of the X-rays.

Becquerel accidently discovered the truth when he decided to continue his experiments. He wanted to run more repeated experiments but the weather in Paris was cloudy, so he stored his uranium crystals and photographic plates in a drawer for several days while waiting for sunny days. When the sunshine finally returned, Becquerel checked the photographic plates to make sure they were not damaged. When he opened the drawer and developed the plate (not expecting to see any image on the plate, because there'd been no sunlight), he was astonished to see an amazingly clear outline of the rock crystal on it even though the rock had not been exposed to sunlight at all.

Becquerel discovered radioactivity in 1896 thanks to the cloudy weather in Paris that week and his decision to store photographic plates and uranium rock crystals in same drawer. But serendipity came into play when he realised he had noticed something really important. A couple of years later Marie and Pierre Curie in Paris started to study the uranium rays, and Marie used the term 'radioactivity' to describe the phenomenon. Becquerel and the Curies shared the Nobel prize in 1903 for their work on radioactivity.

Serendipitous endeavours

All the discoveries above can be used to address the question: 'What is science and what is the scientific endeavour?' As the IB science guide says, 'Scientists also have to be ready for unplanned, surprising, accidental discoveries. The history of science shows this is a very common occurrence.'

So both fortuitous discoveries and difficult findings through careful observation are two sides of the same scientific coin. However, it would be a mistake to suggest that the role of chance and serendipity render scientific knowledge or the scientific process less reliable. Without the extensive shared knowledge of the community, the serendipitous events discussed here might have pass by unnoticed. How many other events of equal importance might we be missing even now?

Key points

- Not only is the progress of science based on meticulous and careful observations through the scientific method, but it also depends on lucky observations known as *serendipitous events*.
- Serendipitous events are not just strokes of luck. Serendipity relies on scientists' knowledge.
- Scientists gain personal knowledge by serendipity, which eventually becomes shared knowledge within the scientific community.

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