The Matthew and Matilda effects: the phenomenon of under-recognition in science. *Assignment written by Diana Grajales Abellán. October 2016. Lund University.*

Modern science is built based on cooperation, trust, competence and fairness between collaborative projects that involve a group of researchers (graduate students, PhDs, post-docs, senior researchers…). Furthermore, it is often seen that the research group extends the network to different collaborations and relationships with other colleagues. This cooperative way of building knowledge facilitates the trustworthiness of society in research (1). However, science is not completely objective, and it can be affected by psychological and social factors that determine the scientific paradigm of the moment, as Thomas Kuhn proposed in 1962 (2). Two good examples of these social factors that compromise scientific objectivity are the Matthew and Matilda effects. In short, the Matthew effect describes that contributions made by "high standing" scientists are the most visible ones, while contributions from less-known scientists are unnoticed. On the other hand, the Matilda effect explains that the work made by women scientists is sometimes seen as work of lower-quality compared to similar work made by their male peers. In this assignment, I will try to review both effects and explain some characteristics examples of both phenomenon.

The Matthew effect was first described by the sociologist Robert K. Merton in 1968. The idea refers to the possibility that research done by well-known and renowned scientists receives greater attention than scientific work performed by emerging scientists. This phenomenon would comprise factors such as number of publications, number of citations, publication in high-impact journals, relevant work at universities, founding, etc. In order words, how famous is the scientist in the topic of interest. At the end, scientists that accomplish with all these factors would be in a "higher position" that would favor future publishing and founding, while those less-experienced and unknown scientists would find more difficulties to have similar work recognized in this *science based-on-hierarchy* world (3).

This social factor is named by the Gospel of St. Matthew: "*for to all those who have, more will be given*" (Matthew 25:29) and it is often seen in our societies, where valuable resources such as increased welfare, political power or economic richness are rising under those individuals, profit organizations or societies that already have them, inducing a *rich-get-richer* effect (4.) Mathematically, the Matthew effect has been

explained by preferential attachment ("*power-law degree distributions*"). Considering a network formed by different nodes and links among them, we would think that a new node would join the network randomly, but in fact the node would have more possibilities of joining nodes that already have a lot of connections (5).

If we think now about how we could apply this preferential attachment in science, in fact we are not far from the mathematical point of view: experienced researchers, with a long career and well-known in the science society, can easily get more connections (publications, founding, collaborations) than the less experienced researchers that no one knows. Moreover, we could also find in this phenomenon the explanation to why some research fields get more attention and more resources than others ("*trendy*" fields such as oncology or neurodegenerative diseases are getting more attention and founding than for example rare diseases).

The work of Merton explored the interviews of Harriet Zuckerman to many Nobel Prize laureates and analyzed numerous data from newspapers, diaries and scientific papers. Basically, Merton explains that rewards in science tends to reinforce the recognized scientists, and recognition starting early in their careers is determinant to the scientific productivity at the end. As an example, Merton said that scientists working at prestigious universities gained more recognition than scientists working at lower universities with the same number of publications (apart from quality). The interviews of Harriet Zucherman also revealed the concerns of some Nobel Prize laureates that repeatedly observed that they got "*disproportionately great credit"* for their contributions to science over the rest of the scientific community, and that their position allowed them to stay at the "top" of eminence, and not falling below that level. In contrast, the scientists below this "top" were continuously expecting to make a "great achievement" that would rarely have reward if they are still unknown (3). The first type of scientists will get the fame and the honors, the prizes and the presence in textbooks that will allow them to survive to posterity. The second type of scientists will continue in their marginal positions, with less power to develop their ideas and "shadowed" by the top scientists.

At this point, it seems clear that by 1968 many people realized that science was still elitist (continuing the same elitist society that characterized the French Academy or the Royal Academy of Sciences in England) and the rewarding system seemed to favor the individuals higher at the hierarchy, those who already accumulated "advantage" in their careers.

But, apart from the eminent scientists, do we know something about the other "forgotten" scientists, or did they remain invisible? The truth is that history has done justice with some of them, even if they did not get the deserved recognition during life, and now we benefit from their work. For example, we know how important is the periodic table of elements in chemistry in all study levels, but his inventor, the chemist Dmitri Mendeléyev (who also proposed the existence of unknown elements at that moment), did not get his honors in life. It is also say that the pressure from other chemist, Svante Arrhenius, prevented him for achieving many awards, including the Nobel Prize. Another case of unfairness is found in the Nobel Prize in Physiology or Medicine in 1952, awarded to Selman A. Waksman for "*the discovery of streptomycin, the first antibiotic effective against tuberculosis*" (6). The truth is that this powerful antibiotic was discovered by Albert Schatz, a student working at Waksman lab, who did all the discovery process and identification of the bacteria that stop the growing of the tubercle bacillus. He also produced the first available streptomycin. Schatz, that was the first author in the paper reporting the discovery, never got any recognition in the following decades, and felt how Waksman got all the honors from the discovery. Once again, was the second author of the paper, the already well-known and renowned scientist, the one that got the glory. Rutgers University made justice in 1994, 50 years after the discovery, awarding Schatz with the Rutgers University Medal. His name can be found in a brief footnote at the Nobel Prize website, but he never received the Nobel Prize. Today, the cure for tuberculosis has saved 49 million lives between 2000 and 2015 (7).

Another Matthew effect case, this time coming from the mathematics field, is the invention of algorithmic information theory. This theory is known as the "*Kolmogorov*" complexity and it was first discovered and described by Ray Solomonoff in 1964. The famous Russian mathematician Andrey Kolmogorov published similar results independently one year after, and the scientific community named the theory "*Kolmogorov complexity*", honoring the well-known mathematician, although he was not the inventor (8). Was it again a question of renown and notoriety to name theory Kolmogorov instead of Solomonoff, despite that Solonomoff was the original inventor? The list of unfairness in the world of science is not short. And, unfortunately, most of the cases remain anonymous.

On the other hand, when the affected scientists are women, the phenomenon is called Matilda effect. The Matilda effect was first described by Margaret Rossiter in 1993, and refers to the deny of contribution of women scientist in research, who have found their work attributed to their male counterparts during centuries (9). Rossiter chose to name the phenomenon Matilda in honor to Matilda Joslyn Gage, a feminist activist that fought for female suffrage in the XIX century in New York. She became especially famous for the criticism of Christianity and participated in writing of the *Woman's bible*, a feminist reinterpretation of the Bible. The book was published in two parts in 1895 and 1898 and raised controversy in the male-dominated society of America.

Rossiter claimed that, even though is difficult to "measure" which scientists should be remembered or ignored, the truth is that during history, women's achievements seem to be rarely remembered. Of course, there are some exceptions that we all know, as Marie Curie (who won two Nobel Prizes and we still hear things from her nowadays) and Maria Goeppart-Mayer, who was co-awarded with the Nobel Prize of Physics in 1963 with Eugene Wigner and Hans D. Jensen for "*their contributions to the theory of the atomic nucleus*" (10). These women were pioneers, and the importance of their achievements were great enough to highlight their names (although in the case of Marie Curie, a lot of help from his husband Pierre Curie was needed to convince the scientific society of Marie's discoveries).

If we do a little memory exercise, can we think of ten female scientists? Will we run out of time or will we able to remember ten names? I will be impressed if people can make that list, but the truth is that most of the people know 1-2 names of female scientists, while they can make a longer list of male scientists. Rossiter describes that not only unrecognized women in their time generally remained so, but other well-known women have since then deleted from history, either by laziness or inertia, or by historians with definite axes to grind (9).

The Matilda effect is more complicated to understand than the Matthew Effect, because women have been suffering gender-based inequalities in almost all civilization that have persisted. It was after the starting at the end of the XIX century of the feminist waves (11) that achieved suffrage and political equality, reproductive rights or equal working conditions, when the criticism of the minimizing of women's achievements in science began to appear. That is the most plausible explanation for all the known Matilda cases we know from the last century and the ignorance of cases from the past.

One anecdotical Matilda effect case is found in the article published by Merton in 1968 and explained in this assignment (3). While Merton is known for being the first describer of the Matthew effect, his original article is based on the citation of Harriet Zuckerman's 1965 doctoral dissertation, although she does not appear as a proper author. Harriet gave her consent to her future husband, but most of the acquisition and analysis of data was done by her and not by Merton.

Worse Matilda effect cases are found during the last century. Perhaps three of the most notorious ones are the cases of Lise Meitner, Rosalind Franklin and Jocelyn Bell. Lise Meitner was an Austrian physicist who worked together with Otto Hahn in the discovery of the uranium nuclear fission and the enormous release of energy, the base of the nuclear weapons developed in the US during World War II. Otto Hahn won the Nobel Prize in Chemistry alone in 1944 (12) and Lise Meitner was only present in a small part of Hahn's speech, despite the nuclear fission discovery was led by both Hahn and Meitner.

Rosalind Franklin was an X-ray crystallographer that is best known for the first DNA X-ray diffraction images, the base of the discovery of the DNA double helix. Franklin died before the Nobel Prize in Physiology or Medicine in 1962, which was awarded to James Watson, Francis Crick and Maurice Wilkins (13), so she could not be a plausible candidate for it (the Nobel Committee does not make posthumous nominations). However, her essential contribution was minimized in the autobiographical book of Watson "*The Double Helix*", Rossiter claimed (9).

The last case of this assignment is the case of Jocelyn Bell, the discoverer of the first radio pulsars when she was a postgraduate student. Her case is another good example also of the Matthew effect, as the glory for the discovery was taken by the well-known scientist: Antony Hewish, the supervisor of Bell's thesis. In the initial paper that described radio pulsars and published in Nature, Antony Hewish was listed as the first author, while Jocelyn Bell's name was listed as the second author (14). Bell had the sole responsibility of monitoring one of the first radio telescopes and she scanned during many years the nature of radio signals before discovering the radio pulsars. During the end of 1960, the discovery was extremely important in the astronomy fields and many physicists started to follow Bell's indications and looked for more pulsars. However, the development of radio telescopes and the discovery of the pulsars awarded by the Nobel Prize in Physics in 1974 only recognized the contributions of Hewish and Martin Ryle, the developer of

the radio telescope (15). Again, the credit of the discovery went solely to the male counterpart and supervisor, Antony Hewish. "*Miss Bell, you have made the greatest astronomical discovery of the twentieth century*", said Iosif Shklovsky at the International Astronomical Union's General Assembly in 1970.

The list of examples is never-ending and, unfortunately, is just one more example of gender stereotyping of women in society: women hardly receive the credit for work done in many fields and their contributions are of lower-quality when they are compared to men with identical work. Apart from the gender oppression that women are still facing nowadays, for progress in science represents a loss of potential. Remembering that women started to be admitted at universities after 1850 and they were subjected to a male-hostile environment, the contributions to science are even more remarkable: they worked with none or less resources than their male peers, they fought against the favor of the science society and they had their work overseen and judged in every level of academia.

Finally, despite the number of scientific women has been increasing over the last years, there is still an underrepresentation of women in top positions in academia. For example, the Nordic countries rank the first position of the World Economic Forum's Global Gender Gap Report, where Sweden occupies the 4th place. The surprise comes when other statistics are examined. Sweden is constantly represented as a model for women equality, but the percentage of female professors in universities is only 23% (16). In fact, the country that has more female professors is Turkey, which is often seen as very conservative. European legislation has improved to balance women career and family obligations (because apparently, women are expected to always fulfill family expectations) leading to paid maternity leave or childcare, but it is not enough.

We must learn from history and promote the role of women as scientists early in school. The world is full of prejudices against women, and we are thankful of seeing this perspective from our *first-world position*, but we are still not exempt from gender discrimination. Rights for women have been achieved in the last 100 years and we are still on the way. We are responsible for remembering women contributions of science and taught them to the new pupils, promote interest in science and be aware of a situation that can appear early in our career as young women scientists.

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