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Is cancer just a question of 'bad luck'?

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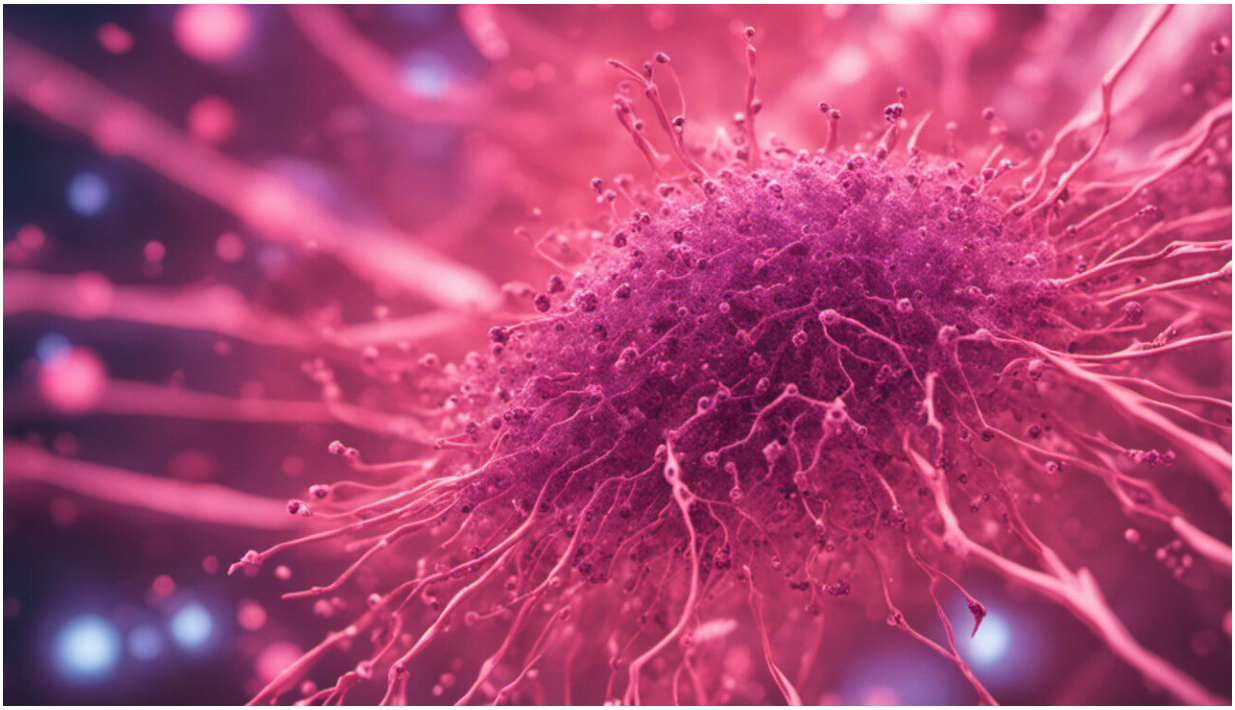

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"Doctor, what caused my cancer?" For doctors, this question is often perplexing. Some of the population risk factors are known, but when it comes to specific cases, only assumptions can be made. However, scientists have a growing understanding of the mechanisms underlying tumour development. Although some of these are rather polemical.

Two US researchers recently sparked controversy with their work on the

role of "luck" in cancer. Their latest article was published in the March issue of the prestigious journal *Science*. The researchers, Christian Tomasetti and Bert Vogelstein of John Hopkins University in Baltimore, showed that the disease is less dependent on hereditary (a genetic predisposition) and environmental risks (such as smoking, or asbestos exposure) than on random mutations (such as DNA replication errors) arising spontaneously in cells as they divide and reproduce over the course of our lifetimes.

In other words, "luck" has a lot to do with it. In a 2015 article, also in *Science*, they had already studied the frequency of cancers in different tissues of the human body. For example, the lifetime risk of lung cancer is 6.9%, as compared to 1.08% for thyroid cancer, and even less for brain and other cancers.

Cancer is more frequent in the colon than the small intestine

These differences are generally ascribed to the greater exposure of specific tissues to risk factors, such as tobacco, alcohol, and ultraviolet rays. But this does not explain why in the digestive system, for instance, the colon is more often affected than other organs. In fact, the small intestine (between the stomach and the colon) is far more exposed to mutation-causing substances than brain cells, yet cerebral tumours are three times more common.

This paradox also holds for hereditary cancers. While the same genetic mutation is responsible for both colorectal and intestinal tumours, the latter remain far rarer. However, in mice with the mutation, the trend is reversed: they develop tumours in the small-intestine more frequently than in the colon.

Tomasetti and Vogelstein therefore hypothesised that the cause for this may lie in the spontaneous mutations occurring during stem cell division (undifferentiated cells). In humans, stem cells renew at a higher rate in the large intestine compared to the small, while the opposite is true in mice. The more often cells divide, the higher the risk of errors in the DNA copying process. This could explain the differences in the frequency of cancers in organs similarly exposed to hereditary and environmental risks.

Tissue renewal rate is linked to higher cancer risk

Their investigation of the presumed link between the known number of stem cell divisions in a given tissue over the course of a lifetime and the risk of cancer in that area revealed a strong correlation. The higher the rate of stem cell renewal, the higher the risk of cancer in that particular tissue. This initial result, based on data from the American population, was backed by a second study published in March of this year, which found the same average correlation across 69 countries.

The researchers then proceeded to isolate the effects of spontaneous mutations from those of other cancer risk factors, both hereditary and environmental. They demonstrated that the majority of cancers are caused by "bad luck" – in other words, by random, spontaneous mutations. "Luck" even plays a significant part in cancers for which environmental causes have been firmly established, like those linked to smoking.

Because these results might lead us to believe that encouraging citizens to adopt healthy behaviours, such as quitting smoking and eating more fruit and vegetables, is not as important as once thought, they generated considerable controversy. The researchers' data was even reviewed by a separate team, who found luck did not play such a significant role after all.

The effects of oxidative stress on DNA

It's worth noting the scientific literature in microbiology, whether or not directly connected to cancer research, offers numerous articles on mutations and DNA damage. In an article published in 2000, American scientist Lawrence Marnett analysed the effects of oxidative stress (attacks on our cells by reactive oxygen species, or "free radicals") and found they were even more significant than those linked to carcinogenic substances. And, oxidative stress is not the only cause of DNA damage, as can be seen in Roel De Bont and Nicolas Van Larebeke's 2004 summary.

In an article published early this year, Anthony Tubbs and Andre Nussenzweig highlighted that each human cell DNA suffers around 70,000 lesions per day. We would not live long if the body didn't have ways of correcting these errors, especially if they all led to us developing tumours. It's important to remember tumours only appear after several control mechanisms have failed.

First of all, the normal repair process of defective cell DNA must have failed. Then, the cell must be allowed to reproduce in a chaotic fashion, meaning the problem must principally affect the genes responsible for cell duplication, or those regulating it. The defective cell also has to escape its naturally programmed self-destruction (known as apoptosis) and the vigilance of the body's immune system, whose work is to eliminate foreign bodies and other dysfunctional elements.

Cell exposure to external or internal mutagens is therefore only one step in a long chain of failures that must take place before a tumour can develop.

The role of stress

At this stage in the discussion on the role of "bad luck" in cancer occurrence, it is worth looking at the particular part played by individual stress, the subject of my work Stress and Cancer: When Our Attachment Plays Tricks on Us (De Boeck). Each of the steps towards a cell becoming cancerous is sensitive to stress and stress hormones. Therefore, chronic physiological stress, which these days is mainly caused by psychological stress, can be considered a direct cause of cancer. I must add, however, there is still open disagreement on the subject.

Chronic psychological stress does in fact accelerate cell reproduction, inducing telomere shortening, the "caps" that protect our chromosomes from wear. This phenomenon was uncovered by the work of Elizabeth Blackburn, who won the Nobel prize in medicine for discovering telomerase. The more these differentiated cells multiply, the higher the risk of random mutations in their DNA. In addition, the more differentiated cells age and die, the more stem cells will divide to make new cells, heightening the risk of cancer development.

But that's not all. Through neuroendocrine processes, psychological stress also affects the oxidative metabolism, DNA repair, oncogene expression and growth factor production. It results in generalised problems linked to chronic inflammation and a loss of effective immune function, as can be seen in the studies cited in my book.

The "bad luck" controversy surrounding Tomasetti and Vogelstein's research provides new food for thought. They point out that, according to the British organisation Cancer Research UK, 42% of cancers can be avoided by changes in environment and lifestyle. In France, the national cancer institute reported a similar ratio of preventable cancers. The figures are both high and disappointingly low. Does this mean there is nothing to be done about the other 60% of cases?

Rather, Tomasetti and Vogelstein suggest ways to fight "bad luck". They advise, among other things, the use of antioxidants in cancer prevention. Given the deleterious processes set in motion by stress, protecting one's psychological well-being could also be an effective weapon against cancer.

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